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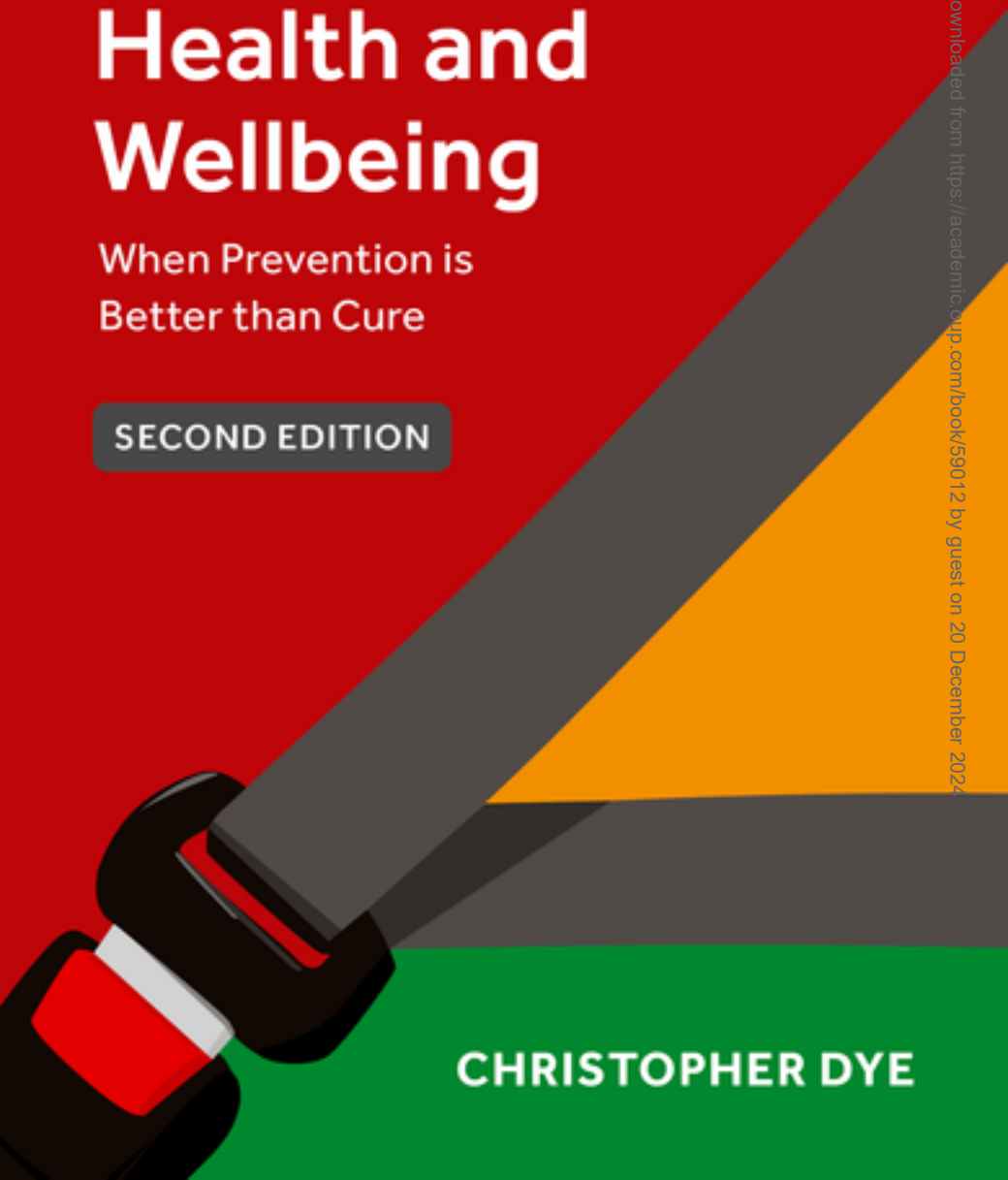
Investing in Health and Wellbeing

When Prevention is Better than Cure

SECOND EDITION



CHRISTOPHER DYE

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Investing in Health and Wellbeing

When Prevention Is Better than Cure

Second Edition

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Preface

> Why wait for people to fall sick? Far better to determine what made people ill in the first place and then take measures to build positive health.
>
> **Roy Porter (*The Greatest Benefit to Mankind*, 1997, p632)**[1]

The proverbial benefits of prevention over cure are, on the face of it, self-evident. A healthy life is one spent free of illness, and in full fitness, until the moment of death. Being sick is detrimental not just because of the suffering it causes, but because it also interrupts a productive and fulfilling life. Taking measures to build positive health (epigraph) has value beyond disease prevention because most people want to do more than survive—they want to flourish and thrive.

But if good health is so desirable why, paradoxically, do we invest so little in protecting and promoting health and so much on treating illness?[2] Abundant statistics highlight the puzzle: across OECD countries in 2019, approximately 1.1 million premature deaths could have been avoided if health services had offered timely and effective medical treatment for illness. But nearly twice as many deaths—about 1.9 million—could have been averted by primary prevention and public health measures.[3]

The causes of preventable illness are well-known. They are hazards from the environment (such as pathogens from polluted water and unsafe sanitation), from metabolic disorders (including diabetes and overweight), and from harmful behaviours (especially alcohol and tobacco use, poor diet, and physical inactivity). In 2019, environmental, metabolic, and behavioural factors accounted, respectively, for at least 20%, 33%, and 38% of all deaths worldwide.[4] These figures align with the observation that economic, environmental, and social factors, in combination, explain a large percentage (typically 45–60%) of the variation in population health, as measured by life expectancy.[5-8]

Prevention appears to be good value for money. Economists have repeatedly concluded that established methods of reducing behavioural, environmental, and metabolic hazards are relatively cost-effective and sometimes

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even cost-saving,[9-18] albeit with exceptions.[19] Prevention also gives financial protection to health services: less disease offsets the rising financial burden of clinical treatment, which is forced upwards by the higher costs of new medical technologies, by market-driven pricing mechanisms for drugs and other medical commodities, by greater healthcare expectations linked to rising incomes, by the growing health and social care needs of ageing populations, and by spikes in demand during emergencies, including pandemics and humanitarian disasters.[3,20-22] Good health creates wealth for individuals and for whole communities, facilitating education, employment, income, and social status. Sickness curtails all of these benefits.

Beyond money, people give intrinsic value to their own health, and to the health of others in society. Population surveys invariably find that health ranks among the most valuable of assets, alongside education, family, friends, and work satisfaction. Health is seen as integral to self-sufficiency and wellbeing, a feeling recently made keener by the physical and mental toll imposed by COVID-19.[23] In society at large, many people (though not all) believe that health equity is an attribute of fairness and justice.

These perceptions of health have a deep history. The word 'health' is rooted in wholeness,[24] a concept that underpins the WHO Constitution (1948). The text of the Constitution was inspired by, among others, medical historian Henry Sigerist: 'health means more than the absence of disease. It has become something positive, a joyful attitude toward life'.[25]

The annals of health promotion and disease prevention list spectacular examples of success. The ten greatest achievements of public health in the twentieth century were, according to the US Centers for Disease Control and Prevention (CDC): vaccination, motor vehicle safety (including seatbelts, book cover), safer workplaces, control of infectious diseases, decline in deaths from coronary heart disease and stroke, safer and healthier foods, lower maternal and child mortality, family planning, fluoridation of drinking water, and the recognition of tobacco as a health hazard (another assessment rated sanitation as the greatest achievement since 1840; Chapter 7).[26] These public health initiatives are directed at families, communities, and populations, as distinct from the clinical care provided to individual patients. They are egalitarian in the sense that safe, population-wide interventions are good for everybody. They are largely preventive, mitigating risk factors for disease such as smoking tobacco and consuming saturated fats. A few rely on improvements in medical care, including better diagnosis and treatment of heart disease and stroke. And some improve health as well as preventing disease, notably through nutrition and family

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planning. Together, public health initiatives accounted for a 25-year gain in life expectancy in the US during the twentieth century—an increase of one year in every four. Some of the discoveries behind these achievements were made by chance, but their deployment happened by choice: there were motives for investing in health as an asset,[27,28] and there were often reasons to promote good health rather than manage the treatment of illness.

Beyond preventive care within health services, health gains are made as a by-product of activities elsewhere in society—through all the links suggested by the Sustainable Development Goals (SDGs).[29] For the architects of the SDGs, health promotion and disease prevention are indispensable tools for surviving the twenty-first century. The SDGs put health promotion and disease prevention at the heart of human development, recognizing that good health depends on, and contributes to, other development goals, which underpin social justice, economic prosperity, and environmental protection.[30,31] They embrace all the subplots of the sustainability movement—natural capital, One Health, social determinants, syndemics, and planetary health. The link between health (SDG 3), environment, society and the economy is framed by the SDGs through action on poverty (SDG 1), education (SDG 4), sustainable cities and communities (SDG 11), and decent work and economic growth (SDG 8), among others.

This seems to be a paradox: there are abundant ways and means to preserve and enhance health that are considered practical, desirable, and economical. And yet health promotion and disease prevention are given low priority, inside and outside the health sector.

The paradox is really a dilemma

Despite all of the preceding evidence, medicine and public health are still largely reactive rather than proactive—organized around the response to specific illnesses and injuries rather than around the means of protecting and enhancing health.

Within health services, funding for preventive care looks persistently low.[5] In 2019, OECD countries, dominated by the world's wealthiest nations, allocated just 2.7% of the money spent directly on health to prevention. In contrast, 94% was spent on inpatient and outpatient services, medical goods (mainly pharmaceuticals), and long-term care.[3] Globally, 116 countries around the world allocated an average of 3.8% of national health expenditure to prevention in 2019 (a total of US$9 trillion across all

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countries), although the percentage was higher during the COVID-19 pandemic.[32,33] The typically low allocation of 2–4% suggests that the budget for promotion and prevention in health services ought to be greater, and not just during a pandemic.

Resolution of this age-old paradox begins with a timeless truth: the benefits of good health come at a cost, and the cost is not always worth paying. If the reasons why people make health choices are understood—how they really value costs and benefits—explanation replaces apparent contradiction, and the paradox disappears. What remains is a dilemma: there are trade-offs among interventions made up and down the causal chain of illness, for example between prevention and cure.

Economists may object that the dilemma has been resolved because they have calculated the costs and benefits, and found that many forms of prevention are worth the money. But the health choices people actually make frequently differ from the choices that economists think they should make; in other words, when the goals, methods, and presumptions of economic evaluation are put to practical test, they often fail. When that happens, an investigation of the reasons for unexpected choices is likely to be more productive than doing another analysis based on the same data and assumptions, leading to the same recommendations, followed by the same muted response.

The public health literature is packed with advice that is not followed, with too few attempts to find out why. A goal of this book is to bridge the gap between professional advice and daily practice: we need an empirical, adaptive approach to investing in health, which recognizes that values are personal and choices are rational (i.e. susceptible to explanation). And where the standard methods of economic evaluation, such as cost-effectiveness analysis, are taken only as a starting point—propositions to be tested and modified, not rules to be followed. Investigations should be openly transdisciplinary because we usually do not know whether health choices hinge on behaviour, culture, economy, environment, physiology, politics, or something else.

Morals and markets

Public health is a vocation for many of its practitioners, and much of the advice offered by them is founded on personal conviction. On its own, however, evangelism for safer and healthier lifestyles is rarely persuasive,

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except among those who already share the same values. The high-minded assertion that *salus populi suprema lex* (Cicero's 'public health must be the highest law') resonates mostly with those who already agree.[34] There are countless contemporary instances of health authorities telling people what they 'must' do, on the naive assumption that everyone is working towards a common goal. In the context of COVID-19, for example, vaccines '*must* be a global public good'.[35] 'Addressing inequality *must* be central to pandemic preparedness.'[36] 'Institutions *must b*e reoriented toward society as a whole, rather than the interests of individuals.'[37] To succeed, efforts to convince dissenters should distinguish between the premise of an argument and its logical consequences. The former is guided by subjective principles (beliefs influenced by authority); the latter depends on objective procedures (choices based on reason). This sits in a philosophical tradition where 'virtue makes us aim at the right mark, and practical wisdom makes us take the right means'.[38] The rightness of virtue and wisdom pose different kinds of questions, which need different kinds of response.

The WHO Constitution argues that 'the highest attainable standard of health is one of the fundamental rights of every human being'.[39] And yet ethical and moral arguments for better health tend to be weak stimuli for action, unless consistent with widely held opinions or conveniently aligned with other priorities.[40] Taking a pragmatic approach to foreign aid (including for health), politician and former UNDP Administrator Helen Clark commented: 'the moral case isn't the one that resonates; the case is that, as developing countries become emerging economies, this opens up markets for goods and services.'[41] Humanists object: E.F. Schumacher thought that markets 'take the sacredness out of life, because there can be nothing sacred in something that has a price'. Reconciliation lies in the view, adopted here, that sacredness adds humanity to utility, and thereby influences the willingness to pay for health and wellbeing. For that reason, the sacredness of health is codified by International Humanitarian Law.[42]

This short introduction sets the scene for the history, principles, and case studies that explore the ways in which people really make choices about health.

Precedents and principles

'Disease prevention' (reducing the occurrence of disease) and 'health promotion' (enabling people to take control of their health) together constitute

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actions that satisfy the WHO definition of health (above).[43] Chapter 1, 'History: the art is long', traces the arguments about prevention and promotion over 5000 years. It shows that all the essential features of the age-old quandary are revealed under history's hugely varying circumstances. History makes no predictions, but reflection is a source of insight. For all of today's choices, though they are contemporary in detail, context, and magnitude, there is guidance in historical precedents.

Principles emerge from precedents: they help interpret the past and generate ideas about the future. Chapter 2, 'Principles: the wisdom of foresight', presents the general proposition: an attractive investment is one that promises major benefits (less disease, more health) to the intended recipients, delivered rapidly, with a high chance of success, and at relatively low cost.

On the assumption that people weigh benefits against costs, albeit imperfectly, Chapter 2 explains why promoting and protecting health are often less appealing than treatment and cure *a priori*. This sets up the book's main challenge: to show how to adjust costs and benefits, real and perceived, for the betterment of health.

Framing the investment dilemma with empirical data, Chapter 2 also finds that much more has been achieved by prevention than is commonly believed—far more than suggested by the 2–4% of health budgets mentioned earlier—though the persistent but avoidable burden of ill-health is reason to achieve still more.

Six case studies

The case studies in Chapters 3–8 take up the main challenge: to seek incentives for investing in better health, as distinct from treating disease, and to explore the constraints and opportunities in different settings. There are six main themes: investment in prevention to relieve the burden of medical treatment in health services (preventive healthcare); managing risk and uncertainty (epidemics); re-setting the perception of hazards (endemic infections); relieving the burden of choice (chronic diseases); adding health to the quality of life (sanitation), and scaling interventions in space and time (climate change).

Chapter 3, 'Preventive care: an affordable dream?' examines investment in health from the perspective of national health services, and the goal of

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Universal Health Coverage. Health promotion and disease prevention are government orphans. Where health is the primary purpose (as in government health departments) prevention cannot compete directly with the clinical treatment of illness; when health is a secondary benefit (as in agriculture, education, environment, and transport departments) it might influence the agenda but rarely has the casting vote. Within the scope of primary healthcare, the leading solution is to invest in prevention first to supplement, and eventually to supplant, as much medical treatment as possible. Empirical evidence from around the world reveals some of the requirements for success, notably protected budgets for preventive care, and matching health service supply with patient demand.

Chapter 4, 'Epidemics: unlikely disasters', focuses on the management of risk and uncertainty. The prevention of rare, unpredictable, diverse, high-impact hazards and emergencies, from earthquakes to Ebola, must balance the cost and efficacy of investment now against the likely risk, timing, and magnitude of a future disaster. The COVID-19 pandemic has illustrated, but not fundamentally changed, the principles of managing unlikely disasters, for example by pooling risks and sharing costs to invest in technology platforms and surveillance systems as global insurance policies.

Chapter 5, 'Endemic infections: normal ways to die', examines how health hazards are perceived as stimuli for action. TB has claimed special status as the cause of more deaths than any other infectious disease in history, and still kills more than a million every year. And yet TB separatism has been a mixed blessing and, as one of today's familiar hazards, TB is rarely considered a public health emergency like COVID-19, Ebola, or pandemic influenza. The solutions include the re-setting of TB as a health hazard, greater integration into primary care, and technological innovation, especially in vaccine development.

Chapter 6, 'Chronic diseases: the burden of choice', asks who is able to choose, and who is responsible for choosing, among options for prevention and treatment. Nowadays most people die, not from infections, but from chronic, non-communicable diseases, predominantly heart disease, stroke, cancers, chronic lung disease, and diabetes. Many of these deaths can be prevented by reducing exposure to major 'risk factors' before the onset of disease, including alcohol and tobacco use; sugar, salt, and saturated fat in food; and physical inactivity. Trying to eliminate these hazards, in the face of short-term personal preferences and powerful commercial pressures,

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poses an assortment of questions. One of them is how to stimulate action now by raising the current value of future ill-health. Another is to resolve a dispute that is central to preventive care—on the balance between individual and social responsibility for public health.

Chapter 7, 'Sanitation: the culture of conveniences', places health in a wider cultural context. Sanitation has long been viewed as an instrument of good health, but effective sanitation depends on aligning health goals with other interests, most of which are more important to users than their health—personal toilet preferences; social norms of defecation; safety of women; water and waste management at household and city scales; energy and food production; crop irrigation and animal husbandry. Sanitation represents the more general problem of how to improve health as a component of personal and societal wellbeing, and of applying solutions devised by local communities on the scale of national populations.

Chapter 8, 'Climate change: a healthy price for carbon' considers how to match investments in health on large and small spatial and temporal scales. Climate change—prevention's greatest challenge—is now recognized as a large and growing threat to health, and leads to anxiety about the health effects of environmental degradation more generally. Mitigation (primary prevention by reducing the atmospheric concentration of greenhouse gases) is most desirable but, as mitigation makes slow progress, the case for local adaptation becomes ever more compelling (secondary prevention through drought resistance, flood protection etc). The causes and consequences of climate change harm health in multiple ways; actions to limits these harms bring health benefits that exceed those obtained by mitigating and adapting to climate change alone.

Chapter 9, 'Future positive: the conditions for health', summarizes the lessons from the case studies. These are the methods and means—different in each setting—of resolving multiple health dilemmas—shifting the balance away from reactive medical treatment, bypassing illness and injury, on the road to WHO's aspiration of health as 'complete physical, mental and social wellbeing'.[39]

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Acknowledgements

This book is about the health choices people make, and why they make them—especially the commonplace decision to favour cure over prevention. The key question is this: faced with a threat to health, or given the chance to become healthier, why do people risk sickness and medical treatment instead of investing up front in their wellbeing? Understanding past choices is the basis for making better ones in future.

The first edition of this book was entitled *The Great Health Dilemma*—'great' because the dilemma is perennial and pervasive, surfacing in every area of health promotion and protection. This second edition has a new title because it expands the idea of 'prevention' as an investment in health, being more explicit about the benefits of making health gains as well as avoiding health losses. How these two kinds of benefit are valued is a matter for investigation, not supposition, but this wider outlook allows for choices that are motivated by the attraction of feeling well, in addition to the threat of becoming ill. And it gives a more comprehensive view of the book's main topics: the provision of health services, epidemic and pandemic preparedness, preventing endemic infections and chronic diseases, and combating illness and injury caused by unsafe sanitation and climate change.

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One of Kurt Vonnegut's eight rules for creative composition was 'write to please just one person'. I hope to have succeeded.

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Abbreviations

ACA	Affordable Care Act
AI	artificial intelligence
AIDS	acquired immune deficiency syndrome
AMR	antimicrobial or antibiotic resistance
ART	antiretroviral therapy
BCG	Bacillus Calmette–Guérin
CEA	cost-effectiveness analysis
CEPI	Coalition for Epidemic Preparedness Innovations
CLTS	Community-led total sanitation
COPD	chronic obstructive pulmonary disease
COVID-19	coronavirus disease
DALY	disability-adjusted life year
DIB	Development Impact Bond
DOTS	directly observed treatment, short course
ESG	environmental, social, and governance investing
ETEC	enterotoxigenic *Escherichia coli*
ETS	emissions trading systems
EV	electric vehicles
FAIR	findable, accessible, interoperable and reusable (data)
FFV	flex-fuel vehicle
GAVI	Global Alliance on Vaccines and Immunization
GDP	gross domestic product
GFATM	Global Fund to Fight AIDS, Tuberculosis and Malaria
GHG	greenhouse gas
GHI	global health initiatives
GISAID	Global Initiative on Sharing Avian Influenza Data
GPEI	Global Polio Eradication Initiative
GRID	gay-related immune deficiency syndrome
GVP	Global Virome Project
GWP	global warming potential
HCM	healthy condition monitoring
HiAP	health in all policies
HIV	human immunodeficiency virus
HLCCP	High Level Commission on Carbon Pricing
HPAI	highly pathogenic avian influenza

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IARC	International Agency for Research on Cancer
ICD-11	*International Classification of Diseases 11th* Revision
IDSR	Integrated Disease Surveillance and Response
IEA	International Energy Agency
IHME	Institute for Health Metrics and Evaluation
IHR	International Health Regulations
IP	intellectual property
IRA	Inflation Reduction Act
IUATLD	International Union Against Tuberculosis and Lung Disease
IWR	Inclusive Wealth Report
LPG	liquefied petroleum gas
LRI	lower respiratory infection
MDG	Millennium Development Goals
MERS	Middle East respiratory syndrome
NCD	non-communicable diseases
NDEP	National Dental Epidemiology Programme
NGO	non-governmental organization
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NIPH	National Institute for Health Protection
NTD	neglected tropical diseases
O&M	operations and maintenance
ODS	ozone-depleting substances
OECD	Organisation for Economic Co-operation and Development
OPP	Orangi Pilot Project
OR	operational research
ORT	oral rehydration therapy
PCP	pneumocystis carinii pneumonia
PEF	Pandemic Emerging Finance Facility
PEPFAR	President's Emergency Plan for AIDS Relief
PHC	primary healthcare
PHEIC	Public Health Emergency of International Concern
PIP	Pandemic Influenza Preparedness
PreP	pre-exposure prophylaxis
PRI	Principles for Responsible Investment
PRRC	Pasig River Rehabilitation Commission
QALY	quality-adjusted life year
R&D	research and development
RITE	Rapid Isolation and Treatment of Ebola
SARS	severe acute respiratory syndrome
SCC	social cost of carbon
SCLP	short-lived climate pollutant

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sd	standard deviation
SDG	Sustainable Development Goals
SDI	socio-demographic index
SDIL	Soft Drinks Industry Levy
SHA	System of Health Accounts
SIB	Social Impact Bond
SLCP	short-lived climate pollutants
SSB	sugar-sweetened beverages
TB	tuberculosis
UHC	Universal Health Coverage
UKHSA	UK Health Security Agency
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UNMEER	United Nations Mission for the Emergency Ebola Response
UPF	ultra-processed food
USAID	US Agency for International Development
VSL	value of a statistical life
WASH	water, sanitation, and hygiene
WHO	World Health Organization
WOAH	World Organization for Animal Health

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1
History

The art is long

> The skillful doctor treats those who are well, the inferior doctor treats those who are ill.
>
> **Pien Ch'iao, Chinese physician (407–310 BC)**

'Prevention is better than cure', but a proverb's short-cut to wisdom often conceals a more circuitous route to the truth. Like other familiar aphorisms, this one also represents a larger goal—favouring not only protection against illness, but also better health and wellbeing. Running over millennia, the recorded history of health promotion and disease prevention is a tale of hope and expectation, risk and uncertainty, truth and perception, science and superstition, power and control, individual and collective action, and of the valued present (Horace's 'seize the day …) versus the devalued future (… put little trust in tomorrow'). The account given here, like most others, is biased towards the well-documented (in English) western world. Its purpose, however, is not to be comprehensive or categorical; rather, it is to show that the main ideas about protecting and improving health have a long pedigree even if, in every age and in every place, they find new interpretations.

Evolution of prevention

For all biological organisms, reproductive success is measured by the number of offspring produced in the next generation. Success for an individual means having more offspring than others. In principle, protecting

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and improving health might produce more descendants than treating and curing illness. If the mechanism of health protection is heritable—that is, transmissible from parent to offspring through the genome—then it would be subject to evolution by natural selection. Alternatively, or in addition, a successful preventive behaviour, once discovered, might be learned and memorized by others, spreading through a population by cultural evolution. Genes and memes are both mechanisms that allow healthy behaviours to spread, by trial and error, through biological populations.

There are abundant examples of health-preserving behaviours throughout the animal kingdom (leaving aside other forms of life).[1-5] *Formica* wood ants use conifer resin to prevent bacterial and fungal infections in their nests.[6,7] European starlings weave aromatic plants into their nests, which retard the hatching of louse eggs and inhibit the growth of nest-borne bacteria. Sheep, horses, and cattle avoid grazing on forage adjacent to recently dropped faeces, which are potential sources of infection.[1] Lobsters, guppies, mandrills, termites, and vampire bats reportedly avoid infected conspecifics.[8] Venezuelan capuchin monkeys rub millipede secretions containing insect-repellent benzoquinones into their fur during the wet season peak in biting insect abundance.[9] The practice of 'infant passing' in *Cercopithecus* and *Presbytis* monkeys probably serves several social functions; one of these might be to boost infant immunity through early exposure to infection.[10] These are all examples of prophylactic rather than therapeutic treatment in animals where prevention has been favoured as an alternative or as a complement to cure. Such observations on primates suggest that healthy behaviours have a long history of biological and cultural evolution in their human descendants, spanning hundreds of thousands of years.

Gambling with fortune

On that timescale, the first inferences about human preventive behaviour are relatively recent. Eating, drinking, washing, and defecating have always been essential for life; nutritious food, clean water and safe sanitation are vital for the preservation of health and the prevention of disease (Chapter 7).[11] The first efforts to manage the distribution of water—with dams and irrigation systems—were driven by the need to produce enough food to live in the Tigris and Euphrates (Mesopotamia, c. 5300 BC), Nile (c. 3300 BC) and Indus (c. 2800 BC) river valleys. Irrigation for agriculture was the precursor to urban water and sanitation systems as small and scattered

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farming villages grew into conurbations, making greater demands to co-operate in providing food and water supplies and on waste management in increasingly dense, sedentary populations.[12]

Based on archaeological evidence from the third millennium BC, the Neolithic peoples of Europe (Orkney Islands), North Africa (Egypt), the Mediterranean (Crete), the Middle East (Israel, Turkey), South Asia (Indus Valley), and central America (Guatemala Maya) had the means and motives to filter and boil water, to design and build flushable cesspits and toilets, connected to communal drains and sewerage systems.[13] The great variety of efforts to purify water, and to remove excreta and other waste, suggest that the environmental causes of illness were understood, and understood to be preventable, with health benefits for individuals and whole communities.[14]

By the third millennium BC (if not before), physicians were carrying out surgery and had accumulated a rich pharmacopoeia of medicinal plants and minerals for healing. The Egyptian practice of applying a poultice of mouldy bread to an infected wound might be the first instance of antibiotic treatment. More than this, and in spite of the prevailing causal model of disease as divine punishment (repentance was cure, not prevention), doctors also gave advice on staying healthy, for instance by washing and shaving the body to prevent conditions now known to be caused by infections.[15] There were treatments for patients and penitents; and for some conditions at least, there were means of prevention, too.

From the sixth century BC onwards, Greek philosophy sharpened the distinction between natural science and theology in pursuit of a reasoned understanding of causes and effects. Knowing the cause is a precondition for reliably preventing the effect. Health and disease were known to be associated with the physical and social environments in which people lived, and with human behaviour.[16,17] Hippocrates' (c. 460–375 BC) *On Airs, Waters and Places* (c. 400 BC) was a guide to preventing illness for settlers in new environments.[18] Some of the advice was common sense: houses should be built in elevated and sunny areas, avoiding marshes and malarial swamps. Some drew on prevailing aetiological theory: dietary regimens and regular exercise could maintain 'a healthy mind in a healthy body', ostensibly by keeping in balance the four humours—black bile, yellow bile, phlegm, and blood.[19] *On the Nature of Man*, part of the multi-authored Hippocratic *Corpus*, saw the body as stable until illness subverted it.[20] Hippocrates and his followers were cautious and sceptical. They put critical reasoning at the heart of medical practice. Their enduring maxim was 'life is short, art is long, opportunity fleeting, experience perilous, and judgment difficult'.

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These ideas are most frequently linked with Greece, but actually co-evolved across the ancient world: during the first millennium BC, humoral balance, now understood as homeostatic regulation, was integral to physiological models of health in contemporary Hindu (Ayurveda) and Chinese societies too.

Prevention was taken seriously by Greek physicians. According to Pliny the Elder (23–79 AD), Asclepiades of Bithynia (c. 124–40 BC) staked his medical reputation on prevention by making a bet with [the goddess] Fortune 'that he should not be considered a doctor if ever he himself fell ill in any way'.[21] He is said to have died by falling down stairs, aged 84, thus escaping the ignominy of terminal illness, winning his bet posthumously, and securing his legacy in preventive medicine.

However, prevention went far beyond the practice of physicians. Underpinning medicine, Greek democracy was an instrument of public health. Individuals and communities were empowered through participatory institutions, emphasizing education and the development of skills to maintain good health. This was health promotion—enabling people to increase control over and improve their health—two thousand years before its rebranding in the twentieth century.[17,22] It was an illustration, too, of the scale on which enabling must take place if health promotion is to succeed (Chapters 7 and 8).

Ever since people began to live in settled communities, they have been forced to relieve themselves of bodily waste, not just personally, but as whole populations. Driven by this sanitary imperative, private and communal toilets linked to drains and sewers became common from at least the third millennium BC. Between 500 BC and 500 AD, public water supply and sewage systems, albeit imperfect systems, were hallmarks of Greece and Rome.

In antiquity, risk was often seen in terms of fate and met with acceptance rather than defiance.[23] But not always: pragmatic traders—Babylonian, Chinese, Greek and Indian, from the second millennium BC onwards—not content with the hand of fortune, also understood how to invest in prevention in the face of uncertainty and adversity.

Their understanding created foundations for the insurance industry. Although risk is not transferable between individuals, the management of risk can be shared among members of a group. Consequently, individuals exposed to losses through common hazards naturally grouped together in order to aggregate the risk, put a price on it, and sell it to investors.[24]

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For shipping, the risk was not necessarily mitigated by financial compensation for loss. It was often non-financial and preventive, for example by steering clear of sea passages known to be dangerous (which required collaboration through record keeping and the exchange of information), by arming ships as a deterrent to piracy, and spreading risk by dividing a cargo among several vessels.

In maritime trading, 'bottomry' contracts provided loans to shipping merchants, secured on the bottom or keel of a ship. When the ship returned to port after a voyage, the loan was repaid with interest. If the shipment was lost at sea, the loan was forfeited by the guarantor. This form of insurance, in which the chance of gain and risk of loss are transferred from merchant to investor, resembles a modern catastrophe bond. It provides guarantors with incentives for prevention—invest in safe ships. Whether the idea of insurance was also applied to the risk of illness in antiquity is apparently unknown, but catastrophe bonds are one of the instruments used nowadays to protect health and life from hurricanes, epidemics, and other disasters (Chapter 4).

Some of the wisdom of Ancient Greece found continuity in Classical Rome, as recorded in practice and proverb. Galen (c. 129–210 AD), 'first among doctors' in the opinion of Emperor Marcus Aurelius, was renowned for his discoveries in anatomy and physiology to inform medical treatments. But he also taught that a physician's priority was to keep people in good health. Galen's physiological model of good health expanded the Greek theory of balancing humours by regulating the 'non-naturals' (as Arab scholars later called them). The non-naturals, or necessary activities, to be regulated were air, food, and drink, sleep and wakefulness, motion and rest, evacuation and repletion, and the passions of the mind, with occasional add-ons including baths, exercise, and sex.[25]

Galen believed in good health and wellbeing for all, founded not merely on philosophy and medicine but on the physical constructs of urban life: gymnasia, aqueducts, bath houses, and communal toilets, streets, and public meeting places. His *Hygiene* (or *On the Preservation of Health*) identified education as vital to learning what was harmful and what was beneficial for health. To the extent that the theory and its practice were beneficial, they did not significantly lengthen life expectancy, which in the Roman Empire (27 BC–476 AD) was typically 20–30 years from birth. Military campaigns carried an obvious risk of disease and injury for adult males, but death rates were far higher in children under five years old.[26] Nevertheless, Galen's synthesis of medical practice in general, and of prevention in

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particular, had wide appeal and astonishing longevity—influencing health and medicine globally for more than a thousand years.

Greco-Roman progress in science and medicine slowed in Europe with the decline of the western Roman Empire from the fourth century AD but continued to flourish in the east. Roman and Byzantine Constantinople became a centre for experimentation and empirical observation. Constantinople, situated at the junction between Europe and Asia, also served as a conduit for Greek and Roman thought into the Islamic world where it developed through cross-fertilization with Indian and Persian medicine.

The Islamic Golden Age (c. 750–1258) produced a succession of polymaths who expanded the concepts and methods of disease prevention and treatment. An array of Arabic medical texts offered technical solutions for environmental pollution and the management of municipal waste. Rhazes (854–925) studied the effects of diet, hygiene, climate, and seasonality on health. Avicenna's (980–1037) encyclopaedic *Canon of Medicine* (1025) synthesized more than a thousand years of medical practice from the Egyptian, Greek, Roman, Indian, Christian, Jewish, and Islamic worlds. The *Canon* was as much a treatise on prevention as on cure, for the dual 'goal of medicine is keeping health and returning it while having disease.'[27]

That which preserveth health is more excellent

Mediaeval Christian Europe (500–1000 AD), maligned as the Dark Ages, was not as dark as commonly portrayed.[28] Instances of scientific censorship in the Middle Ages were outnumbered by examples of the Roman Catholic Church acting as custodian, funder, and promoter of mediaeval intellectual advancement. This was neither doctrinally inconsistent nor scientifically prejudicial: as Aristotle (384–322 BC) had concluded much earlier, if the natural world was governed by God's laws, then studying nature would be one way to understand His purpose. Gaining that understanding may not have been motivated by an earthly need for innovation, but it certainly permitted it. Mediaeval agriculture was one of the beneficiaries: productivity increased with the development of heavy ploughs, crop rotation, and watermills. Besides, the Church's mission was also to serve the needs of the poor, and the remedies for poverty were secular as well as spiritual.

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In terms of public health in Europe, the Middle Ages were bracketed by two major pandemics of plague (later known to be caused by the flea-borne bacterium, *Yersinia pestis*)—the Plague of Justinian in 542 and the Black Death in 1348, with frequent smaller outbreaks in between. The high burden of sickness and death caused by plague, leprosy, and other contagious diseases was a powerful impetus to seek pragmatic solutions. There was no medical cure for plague, so the best tactic was prevention: known or suspected cases, and people who had been in contact with them, were isolated (e.g. for 40 days, 'quarantine') to stop the spread of disease.

Plague and leprosy were not the only targets for disease control. Motivated by the need to curb contagion more generally, public officials created a system of sanitary controls, using surveillance stations, isolation hospitals, and disinfection procedures. Efforts to improve sanitation included the development of pure water supplies, garbage and sewage disposal, and food inspection. Before national public health services were created, the value of personal and public hygiene was understood, if not diligently practised, by citizens and by local authorities alike.

From the early Middle Ages onwards, Latin and Greek translations of Islamic medical texts, including Avicenna's *Canon*, began to appear in Europe. In this convergence of western and eastern thought the idea of prevention resurfaced, for instance in Henry de Bracton's *On the Laws and Customs of England* (c. 1240). Once again, we are told that 'it is better and more useful to meet a problem in time than to seek a remedy after the damage is done'.

Despite the advances made in the millennium since Galen, the task of the physician was still to maintain health by regulating the non-naturals, keeping the body in good 'temperament' and with an optimal 'complexion'.[29] Some facets of fourteenth-century healthcare were decidedly modern, such as attending to the particular requirements of each patient. Because complexion was known to differ among individuals, a satisfactory health regime would have to be tailored to individual needs, at least for those who could afford it. Thus, twenty-first-century personalized or precision medicine, as it is now called, has a history of at least 700 years. Furthermore, the concept of prevention was applied to groups of people as well as to individual patients. Among these public health initiatives, regular prophylactic venesection (blood-letting) was prescribed for entire monastic communities, and healthy regimens were suggested for defined categories of vulnerable people—children or the elderly, or those living in unhealthy environments.

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As the western world emerged from the Middle Ages, Galen's legacy was subjected to increasingly critical examination. Roger Bacon's (c. 1219–92) *Greater Work* (*Opus Maius*), for instance, challenged conventional medical theories with experimental science. Doctors, he argued (after Horace again), should take nothing on authority (later adopted as the motto of the UK Royal Society), specifically church authority; they should instead do their own empirical research.

Whether or not Bacon's advice was followed, the view that prevention trumps cure travelled more or less unscathed through the European Renaissance. Erasmus of Rotterdam (1466–1536), humanist scholar of classical antiquity (who was inclined to overlook advances made in the Middle Ages), reinforced the notion in his book of proverbs (the *Adages*) first published in 1500. He is credited with stating that prevention is better than cure but he did not actually go that far. A more accurate translation of his Latin text is: 'It is better to treat at the beginning of illness than at the end' (*Adage* 1.ii.40). This falls short of true (primary) prevention because the emphasis is on the early diagnosis and treatment of illness, not on removing the underlying cause.

Other writers did promote primary prevention. One of them was Thomas Cogan who, echoing Avicenna's *Canon*, wrote in 1612: 'The art of Physicke hath two principall parts; the one declaring the order how health may be preserved: the other setting forth the meanes how sicknesse may bee remedied. Of these two parts that is more excellent which preserveth health and preventeth sicknesse'.[19,30] Seventeenth-century thinking about health preservation was also captured by the term 'wellness' (c.f. illness), which was first recorded in the 1650s.[31]

An ounce of prevention

Prevention is better than cure, but not at any price. François Duc de La Rochefoucauld (1613–80) complained about the personal cost of staying healthy in 1665: 'what a tiresome malady is that which forces one to preserve your health by a severe regimen'.[32] The burden of keeping fit has always seemed high because, as Thomas Fuller (1609–61) remarked, 'health is not valued till sickness comes'.

The trade-off between costs and benefits was later made explicit in Benjamin Franklin's (1706–90) 'an ounce of prevention is worth a pound of cure', which has been widely generalized from his investigation of fire safety

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in Philadelphia. Because the costs of early versus late intervention were now quantified, at least metaphorically, this rendition of the proverb turns conventional wisdom into a conditional hypothesis. It is pedantic, of course, to ask whether the cost:benefit ratio is actually 1:16 (ounces in a pound); but it is crucial to ask whether benefits exceed costs and under what circumstances. Franklin's own 'prudential algebra' was actually carried out on a balance sheet, which helped him to make difficult decisions with multiple criteria, and to persuade others that he was right. Charles Darwin (1809–82) used a similar technique.

Franklin's approach to fire insurance had a long pedigree. The idea of insuring against risk had been in practical use for millennia (e.g. bottomry contracts already mentioned), including ways of insuring against fire. In AD 67, Nero had allegedly fiddled while Rome burned. He may well have dithered during the conflagration, but he undertook a costly rebuilding of the city thereafter, driven by imperial vanity but guided by, among other practicalities, fire precautions. According to Tacitus, 'from the ashes of the fire rose … a city made of marble and stone with wide streets… and ample supplies of water to quell any future blaze'. [33] New houses had to be built with fire walls, Rome acquired a fire department, and debris from the fire was used to fill nearby malarial swamps.

A century before Franklin, John Winthrop, Governor of Boston, Massachusetts, had in 1631 outlawed the building of homes with wooden chimneys and thatched roofs, which were recognized fire hazards. In Great Britain, the fire insurance industry was given a boost by the Great Fire of London in 1666. In the aftermath of the fire, the Rebuilding Act 1667 was designed to prevent future disasters. Among other safety features, it required houses to have brick fronts, to be of equal height, and to have signs fixed flatly to a wall rather than hanging over the street. Buildings had to be registered with city authorities and were checked against regulations by city surveyors. At first, each insurance company created its own fire department, but the more efficient risk management solution eventually prevailed, where all companies agreed to pool their equipment to create municipal fire departments.[24]

Franklin's contribution in the 1750s was to set up one of America's first voluntary fire services (the Union Fire Company, also known as the Bucket Brigade). But he also realized that if fire is inevitable, and the timing and identity of victims are unpredictable, then it should be possible to set a premium for safety, affordable for everyone, based on the pooling of risk. He therefore established in 1751 the first colonial insurance company, the

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Philadelphia Contributorship for the Insurance of Houses from Loss By Fire. The *Contributorship* put a price on prudence, offering mutual insurance plans, 'whereby every man might help another, without any disservice to himself'. In gambling against ill fortune, this was a triple win: insurance gave peace of mind in the face of a fire risk, and of course it provided financial compensation for losses in the event of fire. But it also encouraged prevention: by inspecting properties to be insured, by setting premiums based on risk assessment, and by rejecting buildings that were not constructed to specified standards.

In the step-by-step development of insurance in the US, Alexander Hamilton created in 1798 a compulsory, tax-financed, health insurance programme for commercial seamen. Centuries after the invention of bottomry contracts (above), the owners of ships returning to the US from foreign countries were obliged to tax every sailor's wages at a rate of 20 cents per month at sea. Illness among some returning seaman placed a burden on local port communities; the money raised by from taxes could 'provide for the temporary relief and maintenance of sick or disabled seamen, in the hospitals or other proper institutions'.[34]

The categorical 'a stitch in time saves nine', attributed to astronomer Francis Baily (1797), also set costs against benefits. In fact, the original, less confident version is better: 'a stitch in time *may* save nine' properly captures the uncertainty associated with investing in the future. Like Erasmus' adage, this form of the proverb calls for early diagnosis of an existing problem, rather than true prevention (no stitch needed at all). These different shades of proverbial wisdom highlight the question, still relevant today, of whether to invest in prevention proper (primary prevention), or to make do with early diagnosis (secondary prevention). The answer to the question depends on the costs and benefits of each strategy (Chapter 2).

The eighteenth-century growth of experimental medicine led to improvements in the means of prevention, as well as creating better treatments. John Pringle's *Observations on the Diseases of the Army* (1752) dealt with problems of hospital ventilation and camp sanitation by advancing rules for proper drainage and latrines, and the avoidance of marshes. He insisted on sanitary measures that reduced the rate of typhus and dysentery, diseases that killed more soldiers than military conflict.

James Lind's *Treatise on the Scurvy* (1754) described his discovery that lemon juice prevented this severe skin and skeletal disease among British sailors (lime juice works too, hence 'limeys'). He did not need to know that scurvy was caused by vitamin C deficiency (vitamins were not discovered

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until 1912 and vitamin C not until 1928). He just needed to be able to design, carry out, and interpret his prototype of the controlled clinical trial.

Lind's study had its roots in the early seventeenth century. In 1601, Captain James Lancaster gave lemon juice to sailors on four ships, but not on another three 'control' ships. The crew of the first four ships stayed healthy, whereas 110 of 278 men died of scurvy on the other three. In 1747, Lind extended the experiment, by giving citrus fruits to scurvy patients who were cured in a few days. The British Navy adopted the policy in 1795 and eliminated scurvy entirely. In 1865, the British Board of Trade did the same for the merchant navy, with the same results. The time from discovery to full implementation in merchant and defence navies was 264 years.[35] To achieve universal coverage, this effective remedy had to overcome the traditions of naval provisioning, the perishability of citrus fruits, and belief in ineffective alternatives, such as barley water and vinegar which contain negligible quantities of vitamin C.

Variolation, the inoculation with smallpox virus to protect against severe disease, was used in China from around 1000 AD. But it was Mary Wortley Montagu (1689–1762) who in 1721 famously introduced variolation to the western world.[36] She had seen the practice and its prophylactic power in Ottoman Turkey. Variolation clearly carried the risk of causing a severe episode of smallpox (with approximately a 2% chance of death), but Montagu nevertheless had her son (in Constantinople) and daughter (in England) inoculated. In August 1721, seven prisoners awaiting execution at Newgate Prison made their own calculation of risk when offered the chance to undergo experimental variolation instead of execution. All were inoculated, all survived, and all were released.[37] The way they eventually died is not known, but it was probably not from smallpox. Setting the certainty of hindsight against the uncertainty of foresight, Benjamin Franklin greatly regretted that he had not made the same calculation on behalf of his own son. Four-year-old Francis Franklin died of smallpox in Boston in 1736 when inoculation was, on balance, probably worth the risk (Chapter 2).[38]

After investigations in the 1760s and 1770s by physicians in England and Germany, Edward Jenner 'vaccinated' in 1796 an eight-year-old boy with pus from the hand of a milkmaid infected with the related cowpox virus (*vacca*, the cow). Jenner then boldly demonstrated that the boy was immune to challenge with smallpox infection. Farmers knew from practical experience that a mild episode of cowpox was protective against smallpox, but Jenner made the point experimentally and almost incontrovertibly. He understood that 'to have admitted the truth of a doctrine, at once so novel

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and so unlike anything that had ever appeared in the annals of medicine, without the test of the most rigid scrutiny, would have bordered on temerity'.[39] However, his study design would not satisfy modern standards of inference or ethics.

The road from smallpox variolation to vaccination is a textbook story of prevention. But variolation was not the only form of immunization with a long tradition. Cutaneous leishmaniasis is a skin disease caused by protozoan parasites in the genus *Leishmania* and transmitted by bloodsucking phlebotomine sandflies. Familiar in antiquity from North Africa across the Middle East to India, leishmanial lesions were variously known, with their geographical identifiers, as buttons (Basra), boils (Aleppo, Baghdad, Delhi, Jericho) and sores (Balkh, Oriental). For centuries, Bedouin, Kurdistani, and other tribal societies had practised leishmanization, the deliberate exposure of children to the parasite by the bite of a sandfly or the inoculation of infectious exudate from an active skin lesion. As with variolation, the aim was to produce a self-healing sore, which would be followed by long-lasting immunity. Immunity would protect against later disfiguring lesions on the face and other exposed parts of the body, unwelcome for anyone but crucial for the marriage prospects of a young woman.[40]

These advances in the scientific understanding of prevention, from lime juice to vaccination, needed a favourable medical, social, economic, and political environment for their application. Like anyone offering the next big idea, Pringle, Lind, Jenner, and other eighteenth-century pioneers had to overcome the scientific scepticism of their peers, plus the predictable opposition of those with vested interests (such as doctors making money out of risky variolation rather than the safer alternative, vaccination).

But there were larger societal forces at work. Through a succession of social revolutions between 1775 (America) and 1848 (Europe), these forces would help to create a more favourable environment for public health. In revolutionary late eighteenth-century Europe and America, the fortunate few in authority faced mounting pressure from the discontented many living in feudal poverty. In America, Thomas Jefferson (1743–826) put health in context: despotism caused disease and democracy liberated health,[41] at least for the White population.[42] Out of the French Revolution (1789–99) emerged the belief that health citizenship was a human right. Preceding that revolution, the pan-European Enlightenment (The Age of Reason, c. 1740–80) fortified the belief that knowledge, reason, and science could drive the betterment and happiness of humankind. Europe's democratic and humanitarian advances leading up to the revolutions of 1848[43]

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provided the backdrop to further advances in public health: medical police (Central Europe); statistical analysis of mortality (France); poor relief (Scotland); the provision of infirmaries (Ireland); and sanitation (England and Wales).[44] The push for better health, and the means of obtaining it were driven by the social and political milieu of the late eighteenth and early nineteenth centuries. Public health can take advantage of, but not create (or today recreate), an environment of opportunity.

Preventive police and the sanitary idea

In nineteenth-century Europe, the use of the word 'sanitation' made it clear that water and sewage were viewed as principal determinants of health and hygiene, even though citizens were also concerned, as they are now, about privacy, comfort, odour, and the physical removal of urine and faeces.[45,46] Unearthing the remnants of historical sanitation systems has drawn attention to the technology, but the implications for social organization are at least as important: advances in sanitation were products of early Indus Valley culture, Greek democracy, Roman administration, and European Enlightenment humanitarianism.

Consequent to the latter, the huge increase in life expectancy enjoyed by people in the industrialized world since the eighteenth century is among the most remarkable biological events in human history.[47,48] No one living in Europe in the 1700s could have foreseen that life expectancy would increase so rapidly above the centuries-long norm of 20–40 years, more than doubling within two centuries. Powered by fossil fuels, the factors that lay behind the increase were cleaner water, safer sanitation, a more reliable supply of high-quality food, and a revolution in microbiology. Technological advances were coupled with accelerating economic growth, suggesting (but not proving) that there were mutually reinforcing, positive feedbacks between processes affecting health and the economy (Figure 1.1).

The rise in life expectancy, driven mainly by the prevention of childhood infectious diseases, began a worldwide epidemiological and demographic transition. As a higher proportion of children survive to adulthood, parents choose to have smaller families. As infectious diseases wane, they are replaced by the chronic, non-communicable diseases typical of adulthood in larger, older populations. In Europe, North America, and other parts of the industrialized world, this transition took place over centuries. In some

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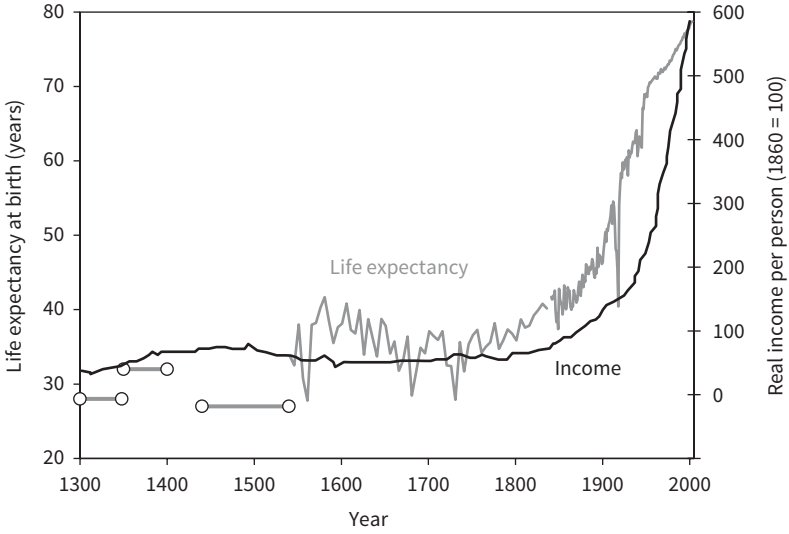

Figure 1.1 Up to 1800, life expectancy from birth in England and Wales was under 40 years (grey lines), but more than doubled between 1800 and 2000. Income per person (black line) also accelerated sharply after 1800, suggesting that there was positive feedback between processes affecting health and the economy, though a third factor(s) could have contributed to both.

Adapted from *The Biologist*, 57, Dye C, 200 years in the history of longevity, pp. 127–30, Copyright (2010), with permission from Royal Society of Biology.

low- and middle-income countries, large reductions in mortality and fertility have taken just a few decades.[49]

Contributing to higher survival rates and longer lives, the nineteenth-century sanitation 'revolution' was so-called, not because it was quick—it spanned the long life of Queen Victoria, 1819–1901—but because it was a national engineering project with benefits for health that were ultimately enormous.

In England, Edwin Chadwick (1800–90), more than anyone else, put health in the broader social, economic, and environmental context. Chadwick has been lauded as the founder of English public health, though he and his collaborators, notably Thomas Southwood Smith, were products of the prevailing, and for them enabling, humanitarian outlook.[41] Elsewhere in Europe, others such as Rudolph Virchow (1821–1902) also championed the cause.

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Chadwick pursued his humanitarian goals by utilitarian means. Guided by Jeremy Bentham's (1748–1832) quest for 'the greatest happiness of the greatest number', to be achieved by a mix of alluring pleasures and painful deterrents, Chadwick became a force for state intervention to address social ills. One such ill was the system of poverty relief provided by the Poor Laws, which was codified principally in the Elizabethan Poor Relief Act 1601. That Act provided social security and welfare as a legal entitlement of all citizens. It was an Act of collective responsibility which, among other things, helped prevent starvation when harvests failed, thereby protecting health as well as averting hunger (see Thomas Cogan earlier).[50]

By the early 1800s, however, the Poor Laws were in crisis: the number of people receiving support had grown, in part because the population of England had started to increase quickly in the late eighteenth century. More claimants increased the burden on ratepayers during a period of economic stagnation.[51] The rationale for poor relief was also in question: some influential political (free market) economists, including Bentham, Adam Smith (1723–90) and Thomas Malthus (1766–1834), believed that the generosity of support invited indolence; it was a disincentive to work hard and save, for personal benefit and for the common good.

In that milieu, Bentham proposed a solution that was severely utilitarian, not benevolently humanitarian: poor people must be encouraged to become financially independent, even though many had little control over the circumstances of their poverty. His argument guided Chadwick as a member of the Royal Commission into the Operation of the Poor Laws 1832, and influenced the Poor Law Amendment Act 1834.[50] The New Poor Law was designed to operate by deterrence, limiting eligibility for relief: it offered support only in workhouses under centralized control. The harsh conditions of the workhouse should be no better than those of the poorest free labourer outside, so that only the most desperate would choose this option. Popular objections to the law were understandable; Chadwick, as its administrator, was said to be the most hated man in England.[44]

But Chadwick genuinely wanted to alleviate poverty, and his efforts did deliver results.[52] The Poor Law Commission stipulated that children should not work more than six hours a day and that employers should be held responsible for accidents in the workplace. The workhouses had infirmaries, albeit with uneven medical care. The Poor Law Amendment Act was followed by the Registration Act 1836, which launched a public vaccination service in England. Under the first Vaccination Act, smallpox

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immunization (replacing risky variolation) was at first optional (1840) and later made compulsory (1853).

The Poor Law Commission gave Chadwick a platform for his greatest achievement—sanitary reform. Obnoxious public stinks or miasmas were not new. They had been a scourge of urban life in Europe since at least the seventeenth century,[53] and were wrongly thought to be linked to airborne disease transmission. Based on that idea, Chadwick skilfully advanced the case for hygiene in the face of complex sanitary politics. *The Means of Insurance against Accidents* (1828) developed his 'sanitary idea' for nationwide improvements to water supply and waste removal. His 1829 paper on 'Preventive Police' was a justification of state-controlled social welfare,[41] and a forerunner to Henry Rumsey's (1809–76) *Essays on State Medicine* (1856) which was, in effect, a practical guide for interventionists and preventionists: investigation, regulation, and prosecution carried out by the medical police.[54-56] Chadwick's crowning glory was his magisterial three-volume, systematic geographical study of health as a basis for action, the *Report on The Sanitary Condition of the Labouring Population of Great Britain* (1842).[13] The *Report* was arguably the most compelling case for state intervention ever written.[57] Its aims and statistical methods were informed by, and in turn influenced, similar analyses in France and America, such as the sanitary reports for New York and Massachusetts published, respectively, in 1845 and 1850.

The 1838 report of the Poor Law Commission promoted, once again, the view that prevention is better than cure: 'the expenditures necessary to the adoption and maintenance of measures of prevention would ultimately amount to less than the cost of the disease now constantly engendered'.[13] Inspired by Bentham's utilitarian ('felicific') calculus, Chadwick estimated 'that this expense [incurred by manual removal of decomposing refuse] may be reduced to one-twentieth or to one-thirtieth, or rendered inconsiderable, by the use of water and self-acting means of removal by improved and cheaper sewers and drains'. He went on to calculate, in an analysis of the kind still done today, 'that by the combinations of all these arrangements, it is probable that the full ensurable period of life, an increase of 13 years at least, may be extended to the whole of the labouring classes'.[58] Thirteen years was a big increase; retrospectively, that estimate looks plausible given the remarkable growth in life expectancy (Figure 1.1).

The ensuing Public Health Act of 1848 was the first occasion on which a British government took national responsibility for the health of its citizens (as distinct from welfare in the Poor Relief Act 1601). Taking responsibility

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in this way inevitably provoked debate about whether preventive policing was in the public interest or an infringement of personal liberty, with echoes in modern disputes about the 'nanny state' (Chapter 6). Sanitary engineering for better health was popular; sanitation as an instrument of social engineering much less so. The indomitable Chadwick personified the division of opinion. To enthusiasts he was a pioneer of social reform; to dissenters he was an agent of political oppression.[41,59]

In parallel with the 1848 Public Health Act, London's Metropolitan Sewer Commission (1848) made household sewer connections compulsory—relieving houses of the stench of cess pits but transferring the problem of pollution to the River Thames. The transition from cess pits to open sewers and faecally polluted rivers played out in different ways across Europe.[53] To remedy the stench emanating from the Thames, the 1852 Metropolis (London) Water Act required all private water companies to move their intakes upstream and to install mechanisms for filtration. In fact, the private water companies were already investing in filtration systems to purify their water supplies, though they acted with varying speed and efficiency. That variation between water companies allowed physician John Snow (1813–58) to test his theory that cholera was caused by a water-borne infection rather than an airborne miasma. During the first seven weeks of London's 1854 epidemic, Snow found that the number of cholera cases per capita was about eight-fold higher in districts supplied by the Southwark & Vauxhall water company (intake downstream, poor filtration) as compared with those supplied by the Lambeth company (intake upstream, improved filtration).[60,61]

As part of the effort to curtail a cholera outbreak in the Golden Square district of London during 1854, Snow famously removed the handle of the Broad Street pump which, it was later discovered, dispensed water contaminated with the faeces of a choleric infant. Handles had previously been removed from pumps during cholera outbreaks in the United States. Snow's action in Broad Street actually had no discernible effect on the Golden Square outbreak, which was already in decline (three-quarters of the inhabitants had left the area). But it was powerfully symbolic of a general truth about cholera: it is a water-borne disease.[61] Indeed, disabling the pump was just one of several precautions taken against cholera (liming of the streets was another) because local authorities remained unconvinced of Snow's argument.

The miasma theory of transmission was deeply entrenched;[62] even the eminent physician William Farr (1807–83) was not convinced that cholera

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is water-borne until 1866. However, it was the reek of the river that provoked action. As so often in public health it took a critical event, on a background of prolonged discontent, to change policy. The Thames had been known for its 'noisome stinking scum' since the 1600s. In the hot summer of 1858 it produced the 'Great Stink'. Overwhelmed parliamentarians promptly gave engineer Joseph Bazalgette the money he needed to rebuild London's sewage system. Bazalgette created a vast network of brick-lined tunnels that carried sewage and wastewater away from the city to treatment facilities downstream (Chadwick wanted to pipe at least some of the sewage to farmers for use as manure). That monumental task was completed in the year of the Public Health Act 1875, which consolidated all previous Acts of Parliament relating to public health during the nineteenth century. As for disease-causing miasmas, the final dispatch of that theory, at least as the cause of cholera, awaited experimental microbiology.

Health was, and is, valued by different people in different ways. For American Seventh-day Adventists of the nineteenth century, healthiness stood next to godliness. Their 'gospel of health' preached prevention, focusing on alcohol, diet, sex, tobacco, and hygiene. With health as a moral imperative, the Adventist Kellogg brothers sought better recipes for a healthy diet. Following experiments in the 1890s with cereal alternatives to meat, they launched the Battle Creek Toasted Corn Flakes Company, permanently changing breakfast menus for millions around the world.[63] The Kellogg brothers would presumably disapprove of their company's present-day range of unwholesome, sugar-coated cereals—Fruit Loops and Frosted Flakes were not anticipated by the gospel of health.[64]

Preventive microbiology

Anton van Leeuwenhoek (1632–1723) had seen 'animalcules', including bacteria, through his new microscope in the 1670s but microbiology did not start to benefit from microscopy for another two centuries.

Preventive microbiology emerged in parallel with synthetic pharmacology. Nature is a rich source of medically active chemicals produced by plants, fungi, insects, and reptiles, which have been used to relieve pain and heal wounds, dating from at least 3000 BC (aspirin precursors in willow bark, opium poppies). The purification and synthesis of drugs began in the eighteenth century and exploded in the nineteenth, yielding

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alkaloids (morphine), anaesthetics (chloroform), barbiturates (barbital), analgesics and antipyretics (aspirin)—a vast dispensary of treatments and preventives.[65]

Louis Pasteur (1822–95) and Robert Koch (1843–1910) were twin peaks in the nineteenth-century landscape of microbiology. Their work began a flood of discoveries about microorganisms as the causative agents of infectious diseases. These breakthroughs in microbiology led in turn to new options for the prevention (vaccines, infection control) and treatment (antibiotics) of specific infectious diseases—and moves towards the greater medicalization of public health.[66]

During an address in 1884, Pasteur commented: 'when meditating over a disease, I never think of finding a remedy for it, but instead, a means of preventing it'. His experimental tests of germ theory (first postulated in the sixteenth century) rapidly generated germ facts. Techniques for staining bacteria made them observable under a light microscope. 'Pasteurization' sterilized fermenting liquids by heat-killing microorganisms. Inoculation experiments with killed or attenuated bacteria and viruses produced prototype vaccines against anthrax, chicken cholera, and rabies. Koch's focus was on microbiology to improve public health measures, including sanitation.[67] Based on his work with anthrax, he devised a set of widely used criteria (Koch's postulates) for inferring that a particular microorganism caused a particular disease. The microorganism must be found in diseased but not healthy persons; cultured from a diseased person; cause disease when inoculated into a healthy person, and be recovered from that person. These criteria guided his work to identify the bacteria that caused cholera (as proposed by Filippo Pacini in 1854) and tuberculosis. Experimental microbiology was extended to insect-borne diseases too. Patrick Manson (1844–1922) demonstrated in 1877 that *Culex* mosquitoes are vectors of filarial worms (*Wuchereria*) and Ronald Ross (1857–1932) in 1897 that *Anopheles* mosquitoes transmitted malaria parasites (*Plasmodium*).

Drawing on the findings of Oliver Wendell Holmes (1809–94) and others, Ignaz Semmelweis (1918–65) deduced experimentally that 'putrid particles derived from living organisms' were the cause of fatal puerperal fever in women after childbirth. The remedy was handwashing with chlorinated water for medical staff working in obstetric wards. Joseph Lister (1827–1912) learned about microbes as a cause of putrefaction from the 'beautiful researches' of Pasteur. He found that carbolic acid (phenol) kept wounds free of infection, prevented septicaemia and gangrene, and aided healing.[20] Out of hospitals and in the community, John Leal's (1858–1915)

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development of chlorine disinfection technology accelerated the elimination of typhoid fever and other water-borne diseases in the US. Beginning in Jersey City in 1908, chlorine disinfection of water had reached a thousand cities across the US by 1918. The scale-up was boosted by a legal ruling in favour of chlorination as an acceptable treatment for the removal of pathogens from drinking water. Analytical developments accompanied microbiology: Florence Nightingale (1820–1910), nurse and statistician, used her 'polar area diagrams' (a type of pie chart) to expose uncomfortable truths about the Crimean War, for example that far more deaths were caused by disease than by battle wounds.

These pioneering discoveries were events on a continuum. From the late nineteenth century onwards, the rapid discovery of antibacterial agents, added to synthetic pharmaceuticals, gave many more options for treatment: antitoxin or serum therapy for diphtheria (1890), arsenic-derived salvarsan for syphilis (1911), and the true antibiotics (derived from bacteria and fungi) penicillin (1928), sulphonamides (1935), streptomycin (1944), cephalosporins (1945), and tetracycline (1948). But the options for prevention multiplied too, with vaccines for human cholera (1885), typhoid (1896), tuberculosis (1921), yellow fever (1936), whooping cough (1939), and Japanese encephalitis (1944). In this new era of antimicrobial technology, there was no trade-off between prevention and cure, but rather a massive build-up of both pharmaceutical armouries.

The causes of the causes

This proliferation of vaccines and antibiotics provided medical reinforcements in the front-line fight against infectious diseases, backed up by large-scale public health measures, and underpinned by improving social and economic conditions. In the first half of the twentieth century, infectious diseases were clearly in decline, but which of these factors was responsible?

The most debated framing of that question was due to professor of social medicine, Thomas McKeown (1912–88), who observed between the 1950s and 1970s that 'health has advanced significantly only since the late eighteenth century and until recently owed little to medical advances'.[68] McKeown argued that the medical profession had attributed too much of the health benefits to its own work—curative medicine—and commandeered disproportionate resources to do so.[68,69] He pointed instead to the effects of market-based economic growth, the rise in living standards,

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improved nutrition (the basis of host resistance to infection) and housing, and to a lesser extent municipal sanitation.[70,71]

Just after World War II, when McKeown began to develop his ideas, recently discovered medical treatments could not possibly account for the decline in infections observed over the preceding decades. The mortality rate from tuberculosis (TB) in England and Wales had fallen from 320/100,000 population in 1870 to 57/100,000 in 1944 (i.e. by about 80%) when the first TB drug, streptomycin, became available (BCG vaccine, created in 1921, was not efficacious against infectious pulmonary TB in adults).[72] Deaths from diphtheria, scarlet fever, and pneumonia had also declined before the discovery of antitoxin, sulfa drugs, and penicillin.[73] In McKeown's opinion, which was shared by others,[74] too much credit went to treatment and too little to prevention.

The shortcomings of McKeown's own analyses and conclusions are now well-known; he probably overstated the benefits of economic growth and understated the impact of public health measures, especially sanitation.[70] He neglected synergies between infection and nutrition.[75] But his question was crucial and stimulated many subsequent investigations, which refined and revised his theory. Samuel Preston (1943–) elevated the role of public health technologies, including water and sanitation, which played a key role in preventing infections and enhancing life expectancy.[48,68,76] Robert Fogel (1926–2013) described the positive association between health (measured by physique, notably height) and nutrition running over two centuries.[75,77] Fogel also saw positive feedback between health and human capital: better nutrition enabled people to grow bigger, stronger, and perhaps smarter, which further boosted income, productivity and health (Figure 1.1).[48,78] Good nutrition could be a win-win—avoiding illness as well as improving health and wellbeing.

At the time of McKeown's analysis, preventive measures, whether more (sanitation) or less direct (nutrition), had taken effect over decades. Antibiotics and other curative drugs had had far less time to make an impact. It is clear now that antibiotics have been responsible for dramatic reductions in mortality, especially since World War II. For instance, TB deaths per capita declined at only 2–3%/year in England and Wales between 1870 and 1944. The establishment of sanitoria and improved living conditions (less crowded houses and workspaces) probably reduced transmission, while improved nutrition increased the resistance to infection. These factors pushed down case incidence but not case fatality; the percentage of TB patients that died remained at 40–50% up to WWII (Figure 1.2). From the

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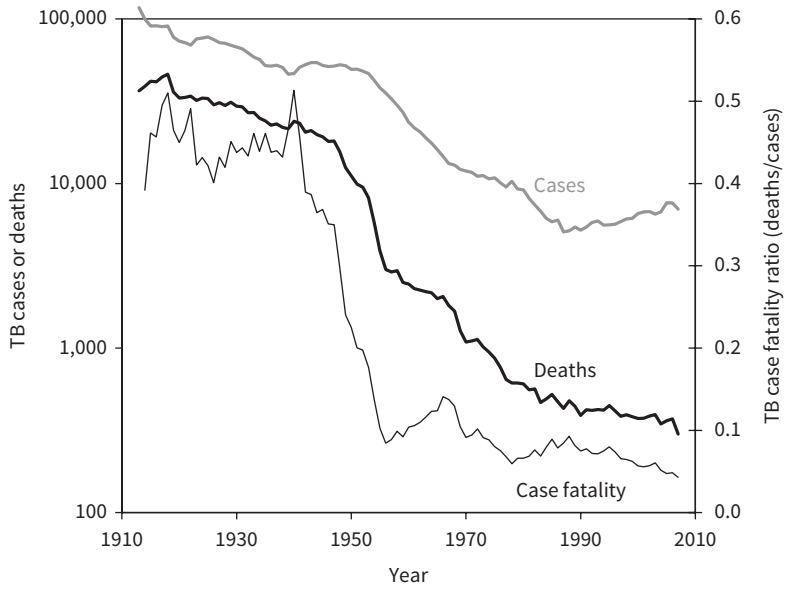

Figure 1.2 Trends in tuberculosis (TB) cases and deaths (left axis) and case fatality ratio (right axis) in England and Wales, 1913–2007.

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1940s onwards, the TB death rate per capita dropped far more quickly—by more than 80% within the decade 1946–55 (at >15%/year)—thanks to the discovery of streptomycin, isoniazid, and other TB drugs. Because medication for infectious pulmonary TB stops transmission as well as greatly improving patient survival, treatment is also a powerful means of prevention.[72] The pertinent question now is whether greater investment in TB prevention could reduce the need for curative treatment; Chapter 5 offers some answers.

Other analyses have found curative treatment to be more effective than prevention at certain times and places. In the United States during the 1990s, the preventive measures then in place (e.g. screening for early disease, immunization) were extending life expectancy by 18–19 months, less than half as much as the prolongation of life from curative measures, roughly 44–45 months.[79,80]

McKeown's advocacy for prevention largely preceded widespread immunization, even though the first vaccines had been created in the

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eighteenth century. Since McKeown, vaccines have massively improved survival worldwide, especially for children after the launch of WHO's Expanded Programme on Immunization in 1974 (now the Essential Programme on Immunization).[81,82]

McKeown had fashioned his argument around the decline in infectious diseases, which were slowly being replaced by chronic, non-communicable diseases in ageing populations—the joint epidemiological and demographic transition. Chronic diseases presented the same question about prevention versus treatment, albeit in a new context. Geoffrey Rose (1926–93), in his influential *Strategy of Preventive Medicine* (1992),[83-85] argued that risk should be measured, and managed, across whole populations.

Investigating high blood pressure (hypertension) as a 'risk factor' for stroke, Rose and collaborators found that three-quarters of attributable deaths occurred in men (London civil servants) with diastolic pressures below 110 mm Hg (normal is <80 mm Hg). They concluded that a large number of men at relatively low risk produce more cases than a small number at high risk. Consequently, for maximum benefit, treatment of hypertension should be population-wide (Chapter 6).

This proposal drew attention to some of the perennial challenges of keeping people healthy, which Rose framed as his own paradox of prevention (c.f. Preface) where 'a measure that brings large benefits to the community offers little to each participating individual'.[85] For individuals who stand to gain little, even a small cost of participation, or a small chance that treatment is harmful, could outweigh the benefits, discouraging compliance.

The investigation of social and economic factors that influence health has a long tradition.[68] Initiatives, such as WHO's Commission on the Social Determinants of Health (2008) have driven action on 'the causes of the causes'[86] from an explicitly ideological position. In the view of this Commission, health inequalities are unfair and putting them right is a matter of social justice.[87] That ethical position echoes the constitution of WHO where 'the highest attainable standard of health is one of the fundamental rights of every human being'.[88] A weakness of the ideological approach, however, lies in an unwillingness to understand alternative values and viewpoints, when progress actually hinges on such an understanding.[89] To make ideology work, it must be turned into instruments of enticement (carrots: financial and other rewards), or censure (sticks: laws, regulations, customs), or both.[90] Broadly speaking, the enticements are to promote

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health, and the censures are to prevent illness, but both potentially have leverage (Chapter 6).

There are other reasons why the case for investing in the social, economic and environmental determinants of health needs to be carefully constructed: although these factors account for as much as 45–60% of the variation in health in populations around the world (Preface), the benefits of tackling them compared with, say, vaccination or reducing blood pressure, are generally less certain and realized over longer time periods. Despite much promotion, action on the social determinants of health has been less effective than hoped. Successes have been local rather than global, for various reasons: an inward-looking agenda on health service coverage, commercial conflicts with health, and an equity agenda that does not necessarily appeal to the public or to policymakers.[89] This limited progress invites a stronger focus on the determinants of choice, alongside investigations of the commercial, social, and technological determinants of health.

The questions at the heart of the McKeown debate—prevention versus treatment, market economics versus publicly funded state intervention—remain alive and relevant today (Chapter 2). These questions apply just as much to environmental health risks as to those linked to society and the economy.[91]

Environmental becomes existential

As the human population surpassed three billion around 1960, it was becoming clear that none of the Earth's life support systems would be free from human influence. The airs, waters, and places of Hippocrates' world were largely fixed sources of risk or benefit to health. Now all natural resources were being shaped and appropriated by human activity, in all parts of the planet, with big consequences for health and wellbeing.

Rachel Carson's (1907–64) *Silent Spring* (1962) was a gospel for the new age of concern about mankind's impact on the environment. Carson persuaded a worldwide audience that the indiscriminate use of pesticides was not only poisoning the environment, it was also poisoning people.

Just as Alexander von Humboldt (1769–1859) had helped to invent an interconnected 'nature',[92] Carson helped turn the 'environment' into a political force. *Silent Spring* was a potent influence on a succession of international conferences that made the connection, systematically and systemically, between environment and health. The United Nations

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Conference on the Human Environment (Stockholm 1972) proclaimed that 'Man is both creature and moulder of his environment'.

The ensuing Stockholm Declaration listed the preventable environmental risks to physical, mental, and social health, specifically 'dangerous levels of pollution, disturbances to the ecological balance of the biosphere, and the depletion of irreplaceable resources'. Stockholm's messages about sustainability resonated with other contemporary analyses: of buying time to feed the world with a Green Revolution,[93] of fairness and intergenerational justice,[94] of the Limits to Growth,[95] and of the flawed economics of natural resource depletion.[96]

Impetus was maintained by the 1987 *Report of the World Commission on Environment and Development* (also known as the Brundtland Commission), which proposed that sustainable development should 'meet the needs of the present without compromising the ability of future generations to meet their own needs'.[97] This definition of sustainability, still influential today,[98-100] laid down a criterion for investing in *Our Common Future*, and for preserving the health and wellbeing of future generations. As in the Stockholm conference, the Brundtland Commission took a systemic, holistic view of development by framing poverty, inequality, and environmental degradation as interdependent challenges. The idea that human activity is a dominant force on the environment is now bound into the unofficial definition of a new geological epoch—the Anthropocene.

The conclusions of the Brundtland Commission are not, of course, shared by everyone—the fossil fuel industry, for example, has a contrary view of business sustainability (Chapter 8).

The goal of the Earth Summit (Rio de Janeiro 1992) was to promote international cooperation on the environment after the end of the Cold War. Its main product, the *Rio Declaration on Environment and Development*, embraced the precautionary principle, which had previously been central to the *Montreal Protocol on Substances That Deplete the Ozone Layer* (1987). In the face of future uncertainty, the precautionary principle is, at first sight, a strong argument for prevention.[101] Whereas physicians treating individual patients are under oath to 'above all, do no harm' [102] (i.e. avoid errors of commission), the precautionary principle says, in effect, 'above all, *allow* no harm' (avoid errors of omission). In truth, both of these principles are ill-defined guides to action because decisions, whether they concern the wellbeing of individuals, populations, or the environment, should balance costs against benefits. The calculation should consider the different consequences of success and failure: for instance, in moral and legal practice,

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actively causing harm is generally considered more culpable than passively allowing harm.[103] To propose safeguards for prevention, following either principle, is not likely to be persuasive unless the benefit (time-discounted and risk-adjusted) outweighs the cost.

Against this historical background, it is widely recognized that the social, economic, environmental, and ethical factors affecting health are interdependent. And yet, in practice, each of these preventable risks to health has been pursued separately, championed for example by different intergovernmental organizations: poverty (World Bank), environment (UNEP), food (FAO), zoonotic diseases (WOAH) and health services (WHO). While specialization gave energy and identity to each technical domain, it neglected the benefits of synergy and connectivity. Various ways of capturing those benefits have been imagined by One Health, EcoHealth, Ecological Public Health, Planetary Health, and Veterinary Public Health. By promoting action across disciplines, these concepts aim to reinvigorate the agenda for prevention in the twenty-first century—the age of sustainable development.[104-107]

Prevention for sustainable development

Early in the twenty-first century, the United Nations has already set two successive sets of goals based on two different propositions for development, the Millennium Development Goals (MDGs 2000–15) and the Sustainable Development Goals (SDGs 2016–30).[108] The SDGs, more than the MDGs, are a potentially powerful force for prevention, but debate persists over which is the better approach for health.

Three of the eight MDGs were linked to health, focusing on mothers, children, and infectious diseases. The health goals were treated separately from each other and from the other five. They were each to be achieved through top-down, prescriptive, time-limited programmes targeting major causes of illness and death in low- and middle-income countries. Not all goals were met but substantial gains were made: the number of people living in extreme poverty, the malaria, tuberculosis, and under-five mortality rates, and the maternal mortality ratio all fell by about one-half or more between 1990 and 2015.[109]

The success of these targeted health programmes was attributed to the provision of medical technologies such as vaccines and drugs. But these successes also relied on functioning health services, run by skilled health

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workers with health information systems, supply chains, and financing and governance mechanisms. Health gains also depend on social, economic, and environmental factors that lie outside the control of the health sector, such as female education and fertility, family income, and access to safe water and sanitation.[109] Without these support services, none of the MDGs could have been achieved.

This understanding of root causes was integral to the MDG upgrade—the fully comprehensive 2030 Agenda for Sustainable Development.[109] The SDGs carry a far greater ambition than the MDGs—to anchor health in development, recognizing that good health depends on and contributes to other development goals, underpinning social justice, economic prosperity, and environmental protection, operating on multiple temporal and spatial scales.[110,111]

The principal goal for health, SDG 3, aims 'to ensure healthy lives and promote well-being for all at all ages'. Universal Health Coverage (UHC), which is central to achieving SDG 3, means that all individuals and communities receive the health services they need without suffering financial hardship (Chapter 3). The advantage of promoting UHC is that it responds to the huge demand for health services, especially primary health care (30% of the world's population still did not have access to essential health services in 2022).[112] A disadvantage is that it places less emphasis on tackling the preventable, root causes of ill health, which reside in the other 16 SDGs.

Those 16 SDGs embrace all of the storylines of the sustainability movement, including health as wellbeing. Wellbeing is a potentially powerful force for better health because it is being tied to national budgets. The Wellbeing Economy Alliance, with leading members Canada, Finland, Iceland, Scotland, Wales, and New Zealand, aims to replace the welfare state with the wellbeing economy.[113] The Welsh Government's Well-being of Future Generations (Wales) Act 2015 set seven wellbeing goals, emphasizing health, prevention (of all adverse events) and sustainability.[114] New Zealand's 2019 Wellbeing Budget targeted UHC but also focused on the social, economic, and environmental conditions that lead to better health.[115]

Despite these successes, the SDG project is seriously flagging. *The Sustainable Development Goals Report* 2023 spoke of 'the promise in peril' and called for a Rescue Plan for People and Planet.[116] It announced that progress towards more than half of the SDG targets was weak and insufficient; for almost a third, it had stalled or gone into reverse, falling well short of key targets on climate, hunger, poverty, and health.[117]

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This sobering mid-term report invites further reflection on the difference between MDGs and SDGs. In MDG style, the Copenhagen Consensus Center published in 2015 *The Nobel Laureates' Guide To The Smartest Targets For The World*. It argued for specific objectives to maximize impact, such as 'lower chronic child malnutrition by 40%', and 'increase immunization, reduce child deaths by 25%'.[118] This chimes with the views of some health professionals who believe that the 'unfinished agenda' of child survival is best served by doing more of what the MDGs prescribed: investing in the well-defined, immediate benefits of primary health care, rather than in the less certain and slowly realized benefits of, say, female education, as promoted by the SDGs.[119] Among SDG advocates are those who point to the MDG dangers of trying to create 'health without wealth'; that is, in selective health fixes that ignore the consequences of, for example, improving child survival without a plan to resolve youth unemployment.[120] COVID-19 provided many more examples: a single infectious disease was a major setback to progress on poverty and hunger, education and equality, among other SDGs.

Clearly, the two approaches to better health are complementary rather than mutually exclusive. The SDG project has emphasized that the goals and targets are 'integrated and indivisible', and yet progress will not be made by trying to tackle everything everywhere all at once. Simplicity and a focus on priorities gave the MDGs political leverage. Any proposed intervention, whether inspired by the MDG or SDG rubric, should be able to pass the same test: that there is a scientifically persuasive case for investment, based on reaslistic costs and feasible returns.

Pay now, live later?

From ancient sanitary systems to contemporary development goals, the circumstances of disease prevention have changed radically over five millennia. The number of people on Earth has increased by a factor of a thousand (from about 8 million to 8 billion); lifespan has more than doubled; the principal causes of death have shifted from infectious diseases in young populations to chronic diseases in ageing populations; there is vastly greater understanding of the causes and effects of illness and death, opening up an array of opportunities for intervention; the emergence of highly effective curative treatments in the eighteenth century underpinned the rise of

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medical power, and undermined the argument for prevention; the practice of public health, and the need for collective action, now take place on greatly expanded geographical (from provincial to planetary) and temporal scales (from weeks to centuries).

And yet the underlying principles of prevention—whether applied to personal, social, economic, or environmental health—have remained the same. Throughout history, aspirations for good health have faced the down-to-earth reality that benefits usually come at a cost—hope is free, but expectation has a price tag. Health promotion and disease prevention are only conditionally better than medical treatment and cure.

If there is a choice between acting sooner (boosting health, preventing illness) or later (treatment and cure), under what conditions will those who have the power decide to favour the former over the latter? Confronting this question, Chapter 2 presents a logical framework for assessing the costs and benefits of investing in health and wellbeing.

Summary

The main ideas about protecting and promoting health run throughout the whole of human history even if, in every age and in every place, they find new interpretations. Spanning more than 5000 years, this chapter introduces all the main themes: illnesses arising from poor sanitation have preventable causes (Neolithic filtration and boiling of water); healthy living is about enhancing wellbeing as much as preventing illness (Ancient Chinese, Greek, and Hindu societies); the choice of prevention over cure depends on the balance of perceived costs and benefits, which depend in turn on hazard, risk, timing, and uncertainty, with multiple historical applications (shipping insurance from 4000 BC, Franklin on fire insurance, Chadwick on sanitation); prevention is for communal as well as personal health (Roman aqueducts and communal toilets); prevention is at a premium in the absence of a cure (fourteenth-century plague); prevention and cure are often complementary (parallel discoveries of antibiotics and vaccines); and the immediate, preventable causes of illness (diet, tobacco) depend on deeper causes, in societies, economies and environments (from Hippocrates to the Sustainable Development Goals). These ideas guide the development of a logical framework for making health choices, the subject of Chapter 2.

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2
Principles

The wisdom of foresight

> Health is an endowment, an asset, a source of capital that needs continuous investment and replenishment
>
> **Andy Haldane (2022)**[1]

Any illness or injury is a failure of prevention—a failure that costs patients and the public at large who pay for medical services. Most people want to lead healthy lives but the benefits of preventing illness and nurturing health come at a cost—measured as money, time, effort, information, trust, and willpower. In deciding whether to invest in health, rather than take a chance on illness and treatment, people weigh the costs against the benefits, anticipating a future of promise and threat while navigating risk and uncertainty.

There are standard economic methods for measuring costs and benefits, but choices about health are usually based on the way subjective values are assigned to objective facts, and those values differ from one setting to another. They influence decisions about health just as they influence decisions about, for instance, preserving the natural environment.[2]

Perceptions of value matter greatly: one big challenge is that spending on prevention is often seen as a cost to individuals and society, rather than an investment in a healthy and productive future.

This chapter lays out the principles of investing in health as an asset (epigraph). These principles are a basis for understanding what choices people make and why they make them. Armed with these insights, it should be easier to see how to lower costs and increase benefits in favour of healthier living.

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The characteristics of prevention

Fineberg identified many of the reasons why prevention is characteristically 'celebrated in principle, resisted in practice'.[3] On his list (with my choice of examples) are:

- Population statistics have little emotional impact compared with personal stories; 'identified lives' trump 'statistical lives': the school groundsman who developed cancer perhaps because of, long-term exposure to glyphosate weed killer, a hazard that is 'probably carcinogenic to humans'.[4,5]
- Lasting behaviour changes are needed in society, which tend to happen in the long-term, between rather than within generations: take regular exercise, choose a healthy diet.[6]
- Commercial interests are detrimental to health: the sale of alcohol, tobacco, sugar-sweetened drinks, and ultra-processed food.[7-9]
- Advice runs contrary to personal, religious, or cultural beliefs: after a death from Ebola virus disease, contact with the body risks exposure to infection.[10]

But all of these reasons could apply to curative treatment too. They offer plausible grounds for not choosing prevention in specific instances. And yet if prevention is commonly disfavoured, as experience suggests, it is likely to have distinctive features, even if they are not decisive on every occasion. Some of these features are listed in Table 2.1; they are prime targets for health promotion and disease prevention.

Health as an investment

Everyone wants to know how best to protect and enhance the value of their assets as they are carried into an uncertain future. They want to minimize the hazards and risks while exploiting the benefits and opportunities.

Investing in health, like any other asset, is a game of chance. A bet placed today has an expected payoff sometime in the future, with a chance of winning more than the stake and a risk of losing it. The return (payoff) on investment (stake) in health is expected to be large when a low-cost

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intervention can eliminate a serious hazard (resilient to loss, through prevention or treatment) or produce a substantial health benefit (making a gain, irrespective of illness), rapidly and with a high chance of success (low risk of failure). In this book, avoiding a loss is aligned with prevention;

Table 2.1 Twelve obstacles to health promotion and disease prevention

Twelve factors that discourage healthy behaviours, diminishing the value of threats and opportunities through their effects on hazards or benefits, risk, time, cost, and choice. These factors are characteristic of promotion and prevention; many more could be listed that also apply to curative treatment

Factor	Challenge	Explanation	Example
Hazard (loss or gain, *H*)	Unvalued	Interventions earlier in a causal chain (upstream) have a greater number of effects than later (downstream curative treatment); greater organization is needed to secure all the benefits of acting earlier.	By defining illness rather than wellness, health metrics are oriented towards disease prevention rather than health improvement. There is insufficient information on the magnitude of interlinked causes and effects to capture the full benefits of prevention e.g. across the SDGs.[134,135]
	Invisible	Successful prevention is less visible than cure (absence of illness); health is not valued until it is lost; some failures of prevention have less impact than others.	Failing to provide clean water is more critical than failing to install a sewage system.[136]
	Unattributable	When ill-health has multiple possible causes and prevention fails, it may not be possible to identify who or what was responsible.	Economic austerity is associated with increased mortality, but the evidence for a causal link is not definitive, weakening accountability.[137,138]

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Table 2.1 Continued

Factor	Challenge	Explanation	Example
Risk (*r*)	Unlikely	A proportion of people at risk who will not become ill (identity unknown) are subject to a prophylactic intervention with a small minimum benefit (peace of mind) and some cost (including possible harm).	In the wake of COVID-19, the risk of another pandemic might still be considered low (a 'once a century event'), relaxing investment in pandemic preparedness.[139,140]
	Uncertain	Uncertainty, including distrust, fosters public unwillingness to follow health recommendations.	Distrust fosters vaccine hesitancy or refusal.[141,142]
Time (*d*)	Untimely	Delayed threats are valued less (time discounted) than imminent ones; rewards obtained with a delay are valued less than those gained immediately; prevention gives way to treatment during emergencies.	In a cholera outbreak, the priority is to detect and treat cases early and monitor water sources, rather than to invest in water and sanitation;[143] delayed rewards are devalued, such as mitigating the effects of climate change[144] or educating girls to improve the health of their future children.[145,146]
Cost (*C*)	Unaffordable	Intervention yields many benefits but is too costly.	Meeting SDG targets for 'safely managed' water and sanitation requires a large increase in capital investment (Chapter 7).[147]
	Unaligned	Health and profit are often conflicting motives for investment.	The 'commercial determinants of health' (i.e. ill-health) include an array of harmful business, market, and political practices.[7,8]

(*continued*)

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Table 2.1 Continued

Factor	Challenge	Explanation	Example
	Ineffective	Intervention efficacy diminishes with more links in a causal chain; per effect, upstream interventions are generally less efficacious than downstream interventions, but have a wider range of effects.	Vaccination is more efficacious than personal hygiene or sanitation in preventing rotavirus infection, but sanitation and hygiene have a wider range of benefits.[148]
	Uncompetitive	Prevention is supplementary to cure in health care services and subsidiary to goals in other sectors.	When health budgets are squeezed, curative medical services are protected before prevention and public health.[60]
	Unfair	Criteria for prevention are more stringent than for cure.	Decision-makers sometimes require prevention to be cost-saving, not merely cost-effective.[3,35,149-152]
	Unfavourable	Cheap and efficacious cures are a possible disincentive for prevention.	Oral rehydration therapy (ORT) might diminish the value of sanitation to prevent diarrhoeal diseases.[112,153] Weight-loss drugs could compromise the prevention of obesity.[154]

making a gain is aligned with promotion though, more precisely, 'health promotion is the process of enabling people to increase control over, and to improve their health'.[11]

For prevention, the payoff is the expected value of eliminating a threat to health. The size of the threat T can be expressed as the product:

$$T = H \times r \quad (1)$$

H is the magnitude of the hazard. For an individual person, H could be the severity of disease, measured for instance by case fatality (the proportion who die). For a population, it is the per capita measure multiplied by the

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number of people affected—for example, the total number of deaths, given the case fatality.

To gain a deeper understanding, *H* could be split into component parts; thus, hazard is a property of the agent that causes illness, and the susceptibility or vulnerability of the person exposed. So the same disease may be more or less hazardous to different people or populations. During 2020, it was quickly discovered that COVID-19 case fatality is higher in older than younger people, and in certain ethnic groups, such as Bangladeshi males in the UK.

The risk *r* is the probability or chance (range 0–1) that the hazard will happen. If $r = 0$, there is no risk and the hazard is not a threat. As *r* increases in size, exposure to the hazard becomes more likely; it is certain when $r = 1$.

Risk (*r*) is not the same as uncertainty, and what is generally called 'risk management' is often 'uncertainty management'. Two kinds of uncertainty surround a measure of risk, imprecision (random error) and bias (systematic error). These are two kinds of error on the value of *r*. A study of smallpox carried out during an infamous 1721 outbreak in Boston (US) illustrates the difference. A total of 5759 people were reported with smallpox in a population of 10,413, giving an estimated risk of disease of $r = 0.553$ during that outbreak.[12] The sample population was large, so that estimate has high precision (small standard deviation of 2.4×10^{-5}). In that event, bias was a bigger source of error: if we want *r* to be the risk of infection for susceptible people, that quantity would have been underestimated because many of the people who were not infected in the 1721 outbreak had probably acquired immunity from previous exposure. In this sense, the calculated risk of 0.553 was too low. People living through smallpox outbreaks in eighteenth-century America weighed the perceived risk of disease against the risk associated with prevention, because inoculation with live smallpox virus could also be fatal. Faced with that dilemma, Benjamin Franklin made the wrong choice, as explained below.

Risk and uncertainty influence health investment in different ways. In general, the magnitude of a threat, and the value of an investment to remove a threat, is greater when the uncertainty is low and the risk is high. The combination can be captured by the ratio of uncertainty/risk, expressed for example as the coefficient of variation (standard deviation/mean).

An underestimate of risk understates a threat (as for smallpox in Boston) but can be corrected by measurement to eliminate bias (systematic error). Uncertainty (random error) can also be reduced by measurement, but not entirely. Insurance is a tool for managing residual uncertainty. As described

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in Chapter 4, the trick is to combine multiple uncertain risks into a single, more precise risk, and share the cost among all who might be affected. Insurance can cover prevention (epidemic surveillance for unpredictable outbreaks) or remediation (emergency services that respond to unpredictable accidents).

Time preferences

The future is generally worth less than the present so the magnitude of a threat or benefit should be discounted over time in Formula (1). An imminent or current hazard (or benefit) is more menacing (or appealing) than a distant one, so it is worth paying more to remove (or obtain) it. From an economic perspective, the standard reason for discounting is this: $100 (or any currency units) invested in health now at an annual compound interest rate of 5% is worth approximately $105 in a year's time, which is five dollars more than it would have been worth if held for a year as cash. $5 is the 'opportunity cost' of not investing. In effect, the original $100 is worth about $95 after a year, with a discount rate of 5%.

The same argument can be applied to health itself, because healthcare transforms resources into health and because healthcare resources can be traded over time.[13] A constant (time invariant) 'social discount rate' for health of 3% per year is commonly used by public health programmes, but with plenty of deviations from that standard. Public concern about the health of future generations suggests a lower value than 3% per year; the lively growth rates of some emerging economies suggest higher values.[14] Empirical studies of the way people value their own health in the face of uncertainty often find that the discount rate is higher in the near term and lower in the more distant future (in other words, the fall-off in value through time is not exponential, as for a constant rate, but hyperbolic for example).[15,16] One reason, among others, to assume that the discount rate declines with time is that the future is less certain than the present.[17] In general, the magnitude and form of the time preference varies for different people in different settings and when facing different health threats.[18] And it may differ for health and for the money that might be spent on health. Time preferences and discount rates for health and money should therefore be investigated, not simply assumed.[19,20]

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Capturing time preference with a simple extension to Formula (1), the expected value today ('net present value') of a threat that might occur at some time in the future becomes:

$$T = H \times r \times d \quad (2)$$

where d is the discount factor (range 0–1), which is smaller for a threat that is expected in the more distant future.

The goal of prevention is to reduce the threat, T, as much as possible and at least cost. The motivation for action will be greatest (large T) when facing a large hazard (big H) that is very likely to happen ($r \rightarrow 1$), and soon ($d \rightarrow 1$); in the shorthand of social science, when the threat is soon, certain and shocking (dubbed the 3S's).

The advantage of primary prevention is that all of the hazard (H) could potentially be averted. The disadvantage is that the hazard is yet to happen, so $r \leq 1$ and $d \leq 1$, reducing the apparent size of the threat, T. For the treatment of illness, by comparison, the threat has already happened: T is bigger because $r = d = 1$, but smaller because treatment removes only a fraction of the hazard, H.

Similar arguments apply to making health gains, as distinct from avoiding losses. Any action taken to improve health or wellbeing (where H stands for health rather than hazard e.g. physical capability for productive work) would be carried out with a given chance of success $r \leq 1$(opportunity rather than risk), delivering benefits sometime in the future $d \leq 1$.

Ideally, the quantities H, r and d would be measured for each type of threat. But even qualitatively Formula (2) makes it clear that there are trade-offs between prevention and cure.

Costs and benefits

The quantity T defines the magnitude of a threat or a benefit to health. Whether it is worth paying to reduce the threat or gain the benefit depends on the cost of the intervention and its efficacy.

Value for money comes from minimizing the cost C (per efficacious application) in relation to the magnitude of the threat removed or benefit gained (T). Value for money may be judged comparatively among options; or with respect to a benchmark, as when there is a maximum acceptable cost (affordability) or a minimum tolerable impact (effectiveness).

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Formulae (1) and (2) offer a simple criterion for choosing prevention over cure. Let C_p be the cost of preventing an episode of illness that carries an imminent ($d = 1$) risk of 10% ($r = 0.1$). If no preventive action is taken, C_e is the cost of effective treatment in the event of illness. Then prevention gives a better return on investment than cure when the ratio of costs C_p / C_e is less than the risk of illness ($r = 0.1$). The greater the risk and certainty of illness, the greater the tolerable cost of prevention.

Formula (2) is more interesting when used to solve a real problem. As described in Chapter 1, Benjamin Franklin bitterly regretted his decision not to inoculate his son, Frankie, against smallpox.[12] Frankie died of the disease aged 4 in 1736. The chance of being infected with the smallpox virus in Boston (US) has been estimated retrospectively at $r = 0.553$ (from a 1721 outbreak, as above), and the chance of dying following exposure was calculated to be 0.146. The 'cost' of inoculation can be measured by the risk of death following this treatment ($C_p = 0.021$), which is smaller than the risk of death without inoculation ($0.553 \times 0.146 = 0.081$). Assuming that inoculation was available on demand, it was much the better option, reducing the risk of death by a factor of four. In fact, the risk of infection for people with no previous exposure was probably higher than 0.553 at the time,[12] which makes inoculation look even more favourable.

Franklin did not have such detailed data, but he did apparently have enough information to reach the same conclusion. Writing to his sister in 1731, he noted that only 2 out of 72 people died after inoculation, compared to one in four who died 'the common way' from smallpox. Following his son's death, Franklin was long haunted by his own aphorism, 'an ounce of prevention is worth a pound of cure'.

This introduction is no more than a starting point for thinking about threat and opportunity, hazard and risk, uncertainty and time, costs, and benefits. Formula (2) poses a series of empirical questions. For instance, does a small risk of exposure (r) to a major hazard (H) present the same threat (T) as a large risk of a minor hazard? Do the metrics used to assess hazard and risk reflect the perceptions that influence health choices? Does delayed preventive action risk a larger and more costly hazard (e.g. a larger epidemic), or even a hazard that can no longer be contained by any level of response (e.g. due to irreversible climate change)? Who incurs the costs of investment and who gains the benefits? Can we pool risks and share costs to insure against unpredictable threats? Or add shorter-term (more valued) to longer-term (discounted) health benefits to increase their net present

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value? What biological, environmental, social, political, and technological constraints influence the type and scale of intervention? How should an intervention be modified in scaling up from novel introduction to full implementation?

Utility and value

Health choices are based not just on facts about hazards, opportunities, risks, uncertainty, timing, and cost, but also on the way these are valued by everyone who has a stake—citizens, governments, non-governmental organizations, businesses, researchers, among others—each of whom may have different goals. This means that economic evaluations, such as cost-effectiveness and cost-benefit analysis, should be based on empirical studies of how people actually value costs and benefits, not on presumptions of how they ought to value them. This puts 'descriptive' or 'positive' economics (agnostic about values) before 'prescriptive' or 'normative' economics (with inbuilt values). A disadvantage of doing this is the loss of standardization, which hinders comparisons across different settings. The advantage lies in understanding the motives for choice in any given setting—not merely stating *what* should be done but examining *why* anyone would choose to do it, and *why* it was not previously done.

Each of the elements of T, plus the cost C, can be measured objectively. The magnitude of a health hazard, H, is usually measured in terms of health (e.g. case fatality), or a compound measure of health (such as Quality-Adjusted Life Years, QALYs), or in terms of money (Box 2.1). Any of these standard measures are satisfactory when there is agreement on the interpretation of value; for instance, when a public health service decides to allocate resources based on the numbers of cases or deaths averted in relation to cost.[21]

But that is a special case. More generally, choice is determined by the subjective evaluation (utility) of objective measurements. In what might have been the founding statement of utility theory, Gabriel Cramer (1704–52) proposed in 1728 that 'mathematicians estimate money in proportion to its quantity, and men of good sense in proportion to the usage that they may make of it'. In short, choice depends on how value is assigned to price.

Daniel Bernoulli (1700–82) turned that idea into his 'expected utility hypothesis' (1738), in which 'utility resulting from any small increase

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Box 2.1 Accounting for health

Single measures of health

The primary statistics of epidemiological studies include the number of new cases of illness per unit of time (incidence), the number of cases of illness at any given time (prevalence), and the number of deaths per unit of time (mortality). To help explain the distribution of health and disease in populations, incidence, prevalence, and mortality are categorized by person (age, sex, ethnicity etc), place (geographical location), and time (days, months, years), and with reference to the denominator population size. Secondary measures of health and disease in populations can be derived from primary records of cases and deaths, such as life expectancy calculated from the number of deaths at each age.

'Health conditions' are, by and large, disease conditions. The health indicators in common use assess illness rather than wellness. That limits the evaluation of desirable health gains, as distinct from preventable health losses. The *International Classification of Diseases* is an aetiological framework, a system of medical codes (55,000 in the 11th revision, ICD-11) created by WHO to classify diagnoses, diseases, signs and symptoms, and the social circumstances of illness and death. The companion *International Classification of Functioning, Disability and Health* (ICF) focuses on the impact of illness and injury on indivduals instead of their causes. It emphasizes that, even with a defined disability, people can lead healthy and functional lives.[155]

Personal health is measured mostly with reference to normal ranges of, for example, blood pressure (systolic <120 mm Hg, diastolic <80 mm Hg), resting heart rate (60–100 beats per minute), fasting blood sugar level (70–100 mg/Dl), and body mass index (18.5–24.9 kg/m^2). Abnormality (outside range) elicits medical care; greater fitness (within range) is a matter of personal choice, often linked to wellbeing (see next).

Compound measures of health

The magnitude of a health problem in a population, and the choice of a solution, are judged absolutely and comparatively. To aid comparisons between diseases with different effects on health, methods have been devised to put illness and death in the same currency. One standard metric, the quality-adjusted life year (QALY), is equivalent to

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one year of life in perfect health. QALYs are intended to measure health gains, for example when tracking patients in clinical trials who, following treatment, live for a number of years with each year weighted by a quality-of-life score on a scale of 0–1. Quality of life is typically measured in terms of a patient's ability to carry out daily activities with freedom from pain and mental disturbance, but QALYs emphasize health (a 'good') rather than quality of life more broadly. In contrast, the Disability-Adjusted Life Year (DALY) measures health loss (a 'bad') and is favoured in studies of disease burden. QALYs and DALYs are standardized measures of utility but exclude many factors that influence subjective values of health and wellbeing, as described in the main text (utility in the broad sense). One DALY is a year of healthy life lost due to illness or injury, calculated as years lost to illness × disability weight + years lost by death. There are numerous reasons to be careful when computing and comparing health outcomes with QALYs and DALYs. One is that quantitative values assigned to the quality of life and disability are debatable. Some formulations devalue the lives of older and disabled people.[156,157] Questionable, too, is the proposition that disability can be equated with death, for instance that 5 × 0.2 (disability weight) years of blindness = 1 year of life lost = 1 DALY. Death is a qualitatively different condition from disability, and perceived in a different way. Apart from specific calculations of economic productivity, death and disability are likely to influence health choices in different ways. So far as possible, different kinds of measures should be kept separate, and assumptions made transparent.[43]

Among the most frequently used tools in economic evaluation, cost-effectiveness analysis (CEA) compares the costs of an intervention against the effects measured with simple (deaths averted) or compound (QALYs gained etc) measures of health.[158] Costs are calculated from the 'ingredients' needed to deliver a healthcare intervention, quantifying the resources required and assigning a price to each resource. The analysis is usually incremental, comparing two or more (usually small) advances in practice within the same health system. Some benchmarks have been set to guide the adoption of new health technologies. In the UK, NICE considers a threshold of less than £20,000 to £30,000 per QALY gained to be cost-effective for the National Health Service.[159] A threshold of US$50,000–150,000/QALY has been used in the US. WHO recommends that the cost per DALY should be less than

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the national per capita gross domestic product (GDP). The two ingredients of CEA, costs and effects, are valuable separately as indicators of whether an intervention is affordable or has sufficient impact, and it should be made clear which indicator is decisive in each setting.

CEA is mostly used to guide government decision-makers who are making a single choice about a single problem on behalf of a single population.[40] Economic evaluation is less useful in showing how, beyond narrowly defined constraints, personal and social choices are really made in health care. In standard form, CEA is unsuitable for large interventions that have multiple or non-linear effects, such as those used to combat pandemics or climate change. Generalized methods of CEA, such as WHO-CHOICE,[158] raise particular questions about who is making the choice in any given setting, based on what motives and values. The answers to these questions are often not made explicit. The broad challenge for economic evaluation is to put the right value on health i.e. the value that individuals, governments, businesses, and others want to use to make decisions. Because these values are often subjective interpretations of the facts, a code of ethics is needed to define what is right or wrong, from the perspective of a community of people whose health is at stake.[160]

Monetary value of health

Appealing to economists, but contentious among health specialists, are methods that put the costs and benefits of prevention or treatment in the same currency—money. As COVID-19 swept through New York state in April 2020, Governor Andrew Cuomo declared that 'we're not going to put a dollar figure on human life'.[161] And yet, like it or not, values are placed on life all the time, implicitly and explicitly. A single currency is useful for trading in a diversity of goods, as when considering the effects of promotion and prevention on health in the broadest sense (WHO's 'state of complete physical, mental and social wellbeing'), and effects beyond health (e.g. other Sustainable Development Goals).

One way of doing this is to calculate the Value of a Statistical Life (VSL), i.e. the amount of money that a person or society is willing to pay to save one anonymous human life. More precisely, VSL is obtained from the perceived value of a small reduction in the risk of death.

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Four main methods are used to compute VSL based on contingent valuation (willingness to pay to lower the risk of death, or compensation required to accept a higher risk of death), human capital (lost earnings), the labour market (wage differentials for jobs that carry different risks of injury or death), and consumer preference (willingness to pay for safety features on consumer products, where cost can be linked to risk of injury or death, e.g. car airbags). The first two of these are based on personal or 'stated preferences'; the last two are based on de facto 'revealed preferences'. Like QALYs and DALYs, estimates of VSL (e.g. range $7–12 million for the US labour market) need careful application. First, we must ask whether any estimate of VSL is fit for purpose, especially when used outside the context in which it was measured, as is usually the case. For instance, estimates based on short-term personal choices (even if they are correct) are unlikely to be the same as those based on long-term social preferences; they address different questions.[162] 'Willingness to pay' should refer to the choice that the decision-maker will actually take in a given setting. Second, an estimate of the benefit/cost ratio > 1, is not on its own justification for choosing an intervention because some other choice might yield a higher ratio. Third, when monetary benefits and costs are calculated in different ways, it is potentially misleading to say that the benefit/cost ratio >1 is cost-saving.[32] Interventions need a cash outlay, but the return on investment defined by VSL is not a cash return. The ratio of benefit to cost, or the difference (benefit-cost)/cost, i.e. the return on investment), should be compared with ratios and differences for competing investments, calculated using the same methods.

Notwithstanding this critical view of VSL, measuring the full personal and social return on investment is the standard to aim for, especially when assessing health benefits as public, common or merit goods, and as a remedy for market failure.[163]

Standard methods of measurement are generally used comparatively, as when evaluating whether prevention is a higher priority than cure. A useful rule for choosing among them is to select the most direct measurement of health (such as case incidence), compromising only when comparisons of different outcomes (disability vs. death, health vs. education) have to be made in the same units (often money).

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Measures of health as wellbeing

Going beyond QALYs, the goal is to capture, in metrics, a vision of health that integrates physical, mental, spiritual, and social wellbeing.[164] Health is one component of wellbeing, along with civic engagement, education, income and wealth, housing and environmental quality, safety, work, and job satisfaction, among others.[165] Health and other aspects of wellbeing tend to be mutually reinforcing. Measures of being and feeling well can be objective (cognitive ability; daily productivity; dietary balance; immune and lung function; microbiome composition; physical strength; healthy life expectancy; rates of suicide, alcohol, and drug abuse) and subjective (life satisfaction; perceived health status), where subjective measures explicitly put a (variable) value on health. Wellbeing is judged at personal (mental health; spiritual wellbeing) and population levels (health inequalities; Universal Health Coverage). Wellbeing embraces indicators of success in populations that go beyond GDP, putting health at the heart of social equity, economic prosperity, and environmental sustainability, leading to priorities for public and private spending that are aligned with the goals for wellbeing economies and the SDGs (see also Chapter 3).[164,166,167]

in wealth will be inversely proportionate to the quantity of goods previously possessed'.[22] In other words, a small sum of money, lost or gained, is more valuable to a poor person than to a rich one. Expected utility modifies the expected value of an intervention in Formulae (1) and (2) above; for the relatively impecunious, a dollar has greater 'marginal utility'.

Mathematically, marginal utility is not always inversely proportionate to assets—that is what intuition would suggest and behavioural studies have shown.[23] Qualitatively, however, the proposition made by Cramer and Bernoulli has far-reaching consequences. It signals that health (and other) choices depend on the subjective utility of costs incurred and benefits gained. It suggests that health, and health as it contributes to wellbeing, does not have objective, universal value; rather the value is subjective and characteristic of each setting.

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Rational choice

Choices are guided by reason and driven by incentives. Criticism of that rational view of decision-making has been drawn around a caricature, *Homo economicus*: a fully informed, flawlessly optimizing egotist, exercising free will (Thaler's fictional 'Econ'[24]). Unlike *H. economicus*, real people are not entirely self-interested (they are not 'rational fools'[25]). Nor are they perfectly logical; they often miscalculate. They do, however, attempt to make reasoned judgements based on motives and incentives.

People are rational in the sense that they have the 'ability to use knowledge to attain goals'.[26] We do not need to adopt here stronger definitions of rationality where, for example, decisions are always internally consistent[23] or 'the best that could have been reached in the light of the evidence'.[27] In reality, a rational choice might be instinctive or reflective, static or dynamic, heuristic or analytical, cognitively bounded or biased, misinformed or based on miscalculation, or the product of moral compromise.[24,28] Which of these applies in any given setting is a matter for empirical investigation.

When an observed choice disfavours prevention, against the advice of economists, it is frequently labelled a 'false economy'.[25,29-34] A better hypothesis is that choice is based on reason, even if the reason is not immediately clear. As Thaler, Kahneman, and other behaviourists have suggested, the problem is not behaviour per se, but the theory of behaviour.[23,24] The way to change behaviour, in favour of better health, is not by insisting that unexpected choices are mistaken, but by finding out why they are made in the first place.[3,35,36] Behaviours are 'irrational' only until they have been explained.

To investigate the basis of choice is an explicitly positive approach to the economics of decision-making.[37] Positive means beginning with an impartial, descriptive study of how and why things are, rather than with prescriptive or normative judgements of how they should be.[38] Positive statements are objective and testable; normative statements cannot be tested because value judgements are irrefutable.[39] The literature in public health economics is dominated by prescription and under-served by description. One reason for this is that governments are primary customers for economic evaluation, seeking advice on how best to allocate limited resources to health care. A public health service often needs to answer a single question on behalf of a single group of people, based on standard cost and benefit calculations. Allocations are typically incremental and conservative rather than radical and transformative; they are designed to inform short-term

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improvements in an existing system of health care, not to change the system for the long-term (e.g. from reactive and curative to proactive and preventive).[34,40] A typical question is: which of two antibiotics, doxycycline or azithromycin, is more cost-effective in preventing sexually transmitted infections between partners?[41] Or with what risk of heart disease should patients become eligible to receive drugs that lower blood pressure?[42] Methodological guidance is of the form: 'all resource use should be valued in monetary terms and be included in the numerator of an incremental cost-effectiveness ratio (ICER). The denominator of an ICER should reflect only health as expressed in quality-adjusted life years (QALYs).'[43] Cost-effectiveness analysis, and related forms of economic evaluation, give useful results under these restricted circumstances—when analysts and decision-makers have agreed on how to assess costs and effects (Box 2.1).

But decisions are not always, or even usually, made in ways that would be recommended by standard appraisals in health economics. Consider, for example, the decisions made by governments in low- and middle-income countries to adopt vaccines that prevent pneumococcal and rotavirus infections, the causes of pneumonia and diarrhoea. These vaccines are cost-effective in countries that still have high levels of child mortality.[44]

And yet there are other criteria for choice. One study of seven low-income countries found that the choice of when and which vaccines to adopt was guided partly by cost-effectiveness, but also by related and unanticipated derivatives of it: short-term costs; funding available from the Global Alliance on Vaccines and Immunization (GAVI); estimates of the burden of disease to be overcome; and local political priorities.[45-47] The decision to adopt a vaccine was not based on the feasibility of adding it to immunization schedules, or on financial sustainability. And it did not depend, apparently, on whether preventing pneumonia and diarrheal disease was thought to be better than treating these conditions in children. In short, the governments of these seven countries were not always framing their choices in the way presumed by standard economic evaluation. And they were not explicitly asking whether prevention is better than cure. This work, following a small number of other investigations, has highlighted the rarity of empirical studies on the process of decision-making in public health.[33,48,49]

In 1997, the United Kingdom government was under pressure to relax the pet quarantine law, which required dogs and cats entering the country to be isolated for six months. The purpose of quarantine was to prevent the reintroduction of rabies into the UK, which had been free of the disease since the beginning of the twentieth century. Abandoning quarantine

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would increase the risk, but this could be offset by vaccination. We estimated that the risk of rabies entering the UK was between 1 in 50 million immigrant pets under the existing quarantine policy, and a maximum of 1 in 10 million with no entry restrictions. However, the politically defined criterion for a new policy framed risk in a different and unanticipated way. The new policy should guarantee that the UK would remain rabies-free for at least 20 years. No policy can guarantee a statistical risk of zero so, after belated discussion between scientists and politicians, the agreed solution was a vaccination regime that would allow one case no more frequently than every 30 years. This was the basis of the pet travel scheme (PETS), which came into force in year 2000.[50]

To have the biggest impact, an intervention should be universal rather than incremental. The speed of uptake of a new idea depends on details that lie behind each of the elements in Formula (2): the nature of the technology (relative advantage and complexity of an innovation); the cost, risk, and uncertainty of investment; how long it takes to transfer knowledge and persuade users (diffusion of ideas); and how well all these elements are understood (mode of communication) and believed (who is in authority). The determinants of diffusion and scale-up are described in the vast literature on 'implementation sicence'.[51-55]

The general point is that, without understanding the purpose of intervention and the basis of choice, it is difficult to influence them, or even to discuss whether policymakers are asking the right question in the first place. The lesson for investigators is that a study of how choices are actually made (criteria, constraints, priorities), and who is making them (often multiple actors), should be carried out routinely, preceding prescriptive analyses of how they should be made (e.g. by cost-effectiveness analysis). The determinants of choice should be as keenly investigated as the commercial, environmental, social, and technological determinants of health (Chapter 1).

'Irrational' choice

When choices about prevention or cure do not conform with the (normative) expectations of health specialists they are often labelled 'irrational'. At worst, seemingly irrational behaviour is dismissed as foolish, ignorant, unwise, or insane.[56] In view of the factors affecting vaccine adoption (above), there is a better approach: investigate the reasons for what appears to be irrational behaviour, leading to so-called 'false economies' in health care.

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One example is the routine medical and dental check-up. 'Healthy condition monitoring' (HCM) (Box 2.2) aims to find and eliminate risks to health before they cause illness (primary prevention), or at least in the early stages of illness (secondary prevention), while avoiding harm. HCM is commonplace, especially in wealthy countries, even though it is generally discouraged. The argument against HCM is that health checks among mostly healthy people do not substantially reduce morbidity or mortality.[57-60] In contrast, targeted screening among people at risk for specific diseases, such as bowel, breast, cervical, and prostate cancer, is considered better value for money, though greater specificity (more cases found per person screened) invariably reduces sensitivity (more cases missed in the whole population).

The apparently unjustified use of HCM could be explained in several ways. One is that HCM does have some benefits, for example in discovering chronic diseases among people who have not yet visited a doctor.[61] This is effective, even if not cost-effective; whether a decision is deemed rational depends on which criterion is used to make a choice. Another is that regular health checks have benefits that are neglected by economic evaluations, such as building trusted relations between patients and doctors (which are made easier if costs are covered by insurance).[62] But HCM can create perverse incentives too: lucrative health screening packages, including unnecessary and potentially harmful tests on vulnerable patients, are an easy source of income for private clinics in some countries.[63] Whatever the reason, the first step is to suppose that there is a discoverable explanation for the persistence of health checks, contrary to recommendations.

Perceptions of hazard and risk

Taking the view that unexpected choices present answerable questions opens the way to investigation instead of censure. Such investigations lead to discoveries about how cultural (ethical, moral, spiritual), psychological (emotional, cognitive, computational, neurological) and social factors (contextual, ethnic) influence decisions, including the way in which different individuals, and different groups of individuals, weigh up costs and benefits to make choices. Surprising behaviours appear to be irrational only until they have been explained.

Behavioural research has amassed a wealth of information about the way costs, risks, and hazards are perceived and valued.[64,65] For a given, objective measure of disease severity, such as case fatality, health hazards seem less

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Box 2.2 International System of Health Accounts (SHA)

Public health refers to all organized measures (whether public or private) to prevent disease, promote health, and prolong life among the population as a whole. Its activities aim to provide conditions in which people can be healthy and focus on entire populations, not individual patients (WHO). 'Prevention is any measure that aims to avoid or reduce the number or the severity of injuries and diseases, their sequelae and complications'.[168,169] In SHA, that definition includes primary prevention (avoiding disease and mitigating risk factors) and secondary prevention (early detection and treatment of disease) but not tertiary prevention (mitigating the effects of established disease or injury), although the principles of prevention described in the main text apply to all three categories. The three categories are a form of triage where tertiary prevention (P3) normally takes priority over secondary (P2) and then primary prevention (P1). Consequently, funding priorities by health services will typically be ordered as P3 > P2 > P1, when funds are limited and come from the same budget. P1 or P2 may therefore need separate, protected budgets to invest in forms of prevention that will eventually reduce the needs and costs of medical care (P3).

The main areas of prevention and public health services covered by SHA are: information, education and counselling (including family planning); immunization (vaccination); early disease detection (secondary prevention); healthy condition monitoring (e.g. pregnancy, children, dental); epidemiological surveillance and risk and disease control; preparing for disasters and emergencies; and health promotion to give people better control over the determinants of their health. These cover, partly or wholly, Essential Public Health Operations, which are core components of resilient health systems.[170]

Although the focus of SHA is on the cost of providing health services, the quantity and quality of services delivered also depends on public demand. Supply and demand are dynamic and interactive.

In the context of health promotion and disease prevention, SHA is limited because it includes only spending for which improving health is the primary purpose.[168] This also defines the scope of promotion and prevention as carried out by health services. SHA covers, for instance, the cost of developing tobacco legislation by a Ministry of Health

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(mainly staff costs under 'governance') but not the costs to government of enforcing legislation on tobacco companies, or of managing tobacco industry lobbying. Nor does SHA offset expenditure with revenue from taxes on tobacco sales.[169]

In this vein, other activities that promote health and prevent disease, but which are excluded form SHA are: developing fiscal and regulatory instruments to protect public health e.g. on active travel (walking, cycling), building standards (part of health governance overall), and food (consumption of fruit, vegetables, lower fat foods, alcohol); costs of enforcing or complying with regulations e.g. on road safety; developing fiscal and licensing policies; treatment and remediation of environmental risks; cash benefits for healthy behaviours (e.g. with respect to food or tobacco).

Some preventive care that is captured by SHA is hidden by conventions of classification: for example, a primary care consultation (visit to the GP) is counted as outpatient curative care, even though visits frequently include a mix of treatment and prevention.

SHA serves as a framework for monitoring health expenditure that contributes to achieving Sustainable Development Goal 3 (SDG 3). However, SHA largely excludes the benefits to and from health of the other 16 SDGs (Health in All Policies, HiAP), which set targets for agriculture, education, energy, environment, housing, transport, water and sanitation, and other sectors. SHA does attempt to collect information on 'health promotion with a multi-sectoral approach'[168] but, even within the limited scope of this category, data are reported by few countries. HiAP is vital for health promotion and disease prevention, and would benefit from a systematic financial accounting system for health in the SDGs, but that does not yet exist.[171,172]

threatening when never previously experienced (typhus in Naples, 1942) or when familiar (tuberculosis) rather than newly encountered (COVID-19); when they cause chronic (HIV/AIDS, diabetes) rather than acute illness (cholera, stroke); when they are seemingly benign (high blood pressure, overweight) rather dreaded (haemorrhagic Ebola, lung cancer, sharks, snakes); when they affect adults rather than children; when natural rather than man-made; and when endemic (steady) rather than epidemic

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(changing). Mathematician Henri Poincare commented in 1900, 'The plague was nothing: fear of plague was much more formidable'.

A single disease can of course evoke mixed reactions: a 2022 survey in the US found that people dreaded an outbreak of mpox (formerly, monkeypox), but they also feared the uncertain risks of vaccination (as they had earlier for smallpox, above).[66]

Radiation and radioactive hazards are exceptionally scary. People are more frightened of nuclear accidents (fewer than 100 deaths ever recorded) and nuclear bombs (roughly 100,000 deaths) than tuberculosis or tobacco (about 100 million deaths each during the twentieth century). In 2023 in Japan, there was strong opposition to ocean discharge of contaminated water from the Fukushima nuclear reactor which was damaged in 2011, even though radioactive tritium is a relatively weak source of beta radiation that is unable to penetrate the skin, and is no threat to seafood. For the release, tritium has been diluted to 1500 becquerels per litre of water, far lower than the Japanese safety level of 60,000 becquerels per litre.

Single, hazardous events have a disproportionate influence on decision-making. In London's hot summer of 1858, parliamentarians were overwhelmed by the 'Great Stink' emanating from the heavily polluted River Thames. Coupled with outbreaks of cholera and typhoid, the stench precipitated action long-planned action by the Metropolitan Board of Works—Parliament funded a massive upgrade of the sewage system (Chapter 1).

By the early 1950s, London had a cleaner river but heavily polluted air. It took 'the UK's greatest peacetime disaster',[67] the lethal 'Great Smog' of December 1952, to trigger the Clean Air Act (1956), which restricted the use of toxic heating fuels and established smoke-free zones in heavily populated areas.[68,69] Likewise, cigarette smoking was finally banned on all London Underground trains and stations after the Kings Cross fire of 1987.[70] Given the well-known effects of smoking on health, there was mounting pressure for a ban, but the final decision was prompted by fire safety, rather than by the argument that smoking damages health.

Because the impact of an event is often judged not by an absolute number but a relative one, change from a point of reference is critical.[38] 'News' commands attention. In the US, after yet another mass shooting (four or more people injured or killed) on 31 May 2019, Senator Elizabeth Warren pointed out that everyday gun violence, which contributes to far more deaths annually than mass shootings, is underreported because it is considered to be normal.[71] Thirteen people were shot dead during a single incident at a government building in Virginia Beach. And yet gun violence claimed a total

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of 39,599 lives in 2019; 15,509 were homicides, accidents, or defensive acts, 24,090 were suicides. The great majority of incidents were not mass shootings. The annual number of gun deaths has continued to rise, reaching 44,290 in 2022, an average of 120 fatalities every day.[72] In the US, firearms are the leading cause of death among children aged 1 to 19 years.[73]

Strong reactions to rare events with major consequences are the norm rather than the exception.[74] So, too, are weak reactions to harms and hazards that become everyday occurrences, especially when some other crisis suddenly becomes more important. Recognizing these facts has the potential to turn strong public reactions into more measured political responses that could, even with forceful opposition from the gun lobby, help to minimize the total number of gun deaths in the US each year.

The 'public health approach' to violent crime aims first to prevent, rather than criminalize, injuries from guns, knives, and other weapons by understanding the characteristics of offenders and their victims.[75,76] 'Focused deterrence' strategies, based on epidemiological evidence, work by convincing would-be perpetrators that they have a high chance of being caught and punished for crimes such as public drug dealing.[77] The deterrent is a threat measured by the chance (risk) of getting caught and the ensuing punishment (hazard), not by the punishment alone.

A hazard is seen as more of a threat when close and personal—when the victim has an identity. The death of a named patient today caused by a failure of treatment (error of commission) is perceived to be more critical than an anonymous future death caused by a failure of prevention (error of omission). The rule in clinical medicine to 'first do no harm' tends to be more compelling than the public health equivalent, 'first allow no harm' (the precautionary principle; Chapter 1).

Stories about individual people are compelling especially when they reflect general truths rather than exceptional experiences. Between 23 June and 10 July 2018, 12 boys and their football coach were trapped in a flooded cave in Thailand, attracting continuous attention from the world's media. It is clear why the incident held a global audience spellbound: they were children, each with character and identity, the rescue was full of daring and suspense with an uncertain outcome, and the Thai authorities were in the spotlight. All 13 were safely rescued, and stories about the subsequent lives of the footballers appear regularly in the news. During the same period, 214 anonymous African migrants attempting to cross the Mediterranean drowned in two separate incidents off the Libyan coast. That drew far less attention because such incidents had become routine.[78]

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Actions are driven by perceptions as well as facts. Consequently, certain environmental effects on health attract greater attention and provoke a swifter response than others. One survey of US news networks found that stories about food shortages (some of which are linked to climate change) were included in only 3% of news bulletins, whereas earthquakes featured in 30% of bulletins, despite the far greater number of deaths linked to hunger than to seismic events.[79] Food shortages are more likely to stimulate action when impersonal statistics and the technicalities of malnutrition are translated into personal stories about hunger and starvation.[80] Public concern about the growing number of natural disasters may help to explain why the death rate in each disaster has fallen markedly over the past century—due partly to improved early warning systems and more effective emergency responses (Chapter 8).

Judgements of risk are based on reason (deliberative), emotion (affective) and familiarity (experiential).[81] Risks tend to be downgraded when they are voluntary rather than imposed, predictable rather than unpredictable, pleasurable rather than painful, controllable rather uncontrollable, and when they come from a trusted rather than an untrusted source. Uncertainty about the cause of uncontrolled 'infantile paralysis'(poliomyelitis) in New York in 1916 caused panic, leading to the pointless slaughter of cats and dogs (the virus is transmitted person-to-person, mainly via stool).[82]

Even if the chance of a threat happening has been accurately measured and is known to all, some people will bet on their luck (risk-prone) while others feel they are better safe than sorry (risk averse). Among 70 people receiving treatment for opioid use disorder in a community-based centre in the US, those who were willing to make risky bets in a game of chance were also more likely to relapse to drug use.[83] When people are offered screening tests for colon, breast and prostate cancer, and told that experts have conflicting opinions about the value of these tests, those who are more averse to ambiguity are less willing to be tested — they perceive screening to have lower benefits and greater harms.[84,85] Differences in expert opinion can put doubting patients at risk, if they underestimate the benefits of screening.

Gambling with fortune carries the prospect of making gains and incurring losses, and equivalent gains and losses are not necessarily valued in the same way. Experimental tests of 'prospect theory' have found that a loss, of money for example, tends to be valued more than an equivalent gain. And because people dislike losses more than they like gains, they are more willing to take risks to avoid those losses.[86]

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Loss aversion ought to favour prevention but the loss of health is not like the loss of money.[38] There are at least two possible reasons. First, good health is often taken for granted; the unworried well do not value their health until it is lost ('you don't know what you've got till it's gone'[87]). More insidiously, poor health, linked for example to diet, inactivity, and obesity, may come to be accepted as normal by individuals and by society, so there is no reason to do anything about it.[38] Poor health in populations could even be exacerbated when unhealthy traits become normal, such as socially acceptable rises in body mass index and preferential (assortative) mating among obese people.[88,89] Second, better health might not hold much value for people who already feel healthy, especially if efforts to improve health incur immediate costs (money, time, effort) but yield only delayed benefits (taking physical exercise, giving up smoking, ensuring children have a healthy diet). In short, the application of prospect theory to health promotion and disease prevention needs to be probed more deeply.

For financial investments, assets that are more volatile offer the chance to make greater gains, but also greater losses. Similar trade-offs apply to health as an asset: extreme training for sporting success brings greater fitness, but also greater risks of injury. More potent or higher-dose medical treatments are generally more efficacious but also more likely to have adverse side effects.

Behavioural economics has become a rich source of testable ideas, not just to explain apparently irrational misbehaviours, but also to change them for the better.[90-94] The COM-B model emphasizes Capability and Opportunity, plus Motivation, to drive Behaviour change,[95] for example to reduce SARS-CoV-2 transmisison.[96] The UK government's Behavioural Insights Team (one of hundreds around the world) aims to make progress through 'radical incrementalism'.[97] The 'Nudge Unit' has, for instance, used social norms to encourage the payment of taxes: advertising that most people pay their taxes on time persuades others to do so too. They and other investigators have improved adherence to tuberculosis (TB) treatment, for example by text messaging reminders, and by allowing patients to submit video evidence that they have taken their medication, instead of having to visit a clinic.[98] Changing default options, such as switching from opt-in to opt-out, has increased recruitment to pension plans and organ donor schemes. However, a nudge is sometimes a small stimulus with a correspondingly small effect, as for the uptake of influenza vaccination in Denmark.[99] Furthermore, none of these successes guarantee others: the

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proposal that a nudge can favourably change behaviour is one plausible idea, not a universal truth.[100-102]

Besides, nudging can encourage adverse health behaviours too. 'Dark nudges' try to persuade consumers to act against their best interests, and 'sludges' use cognitive biases to make behaviour change more difficult. Both are used, for example, by the alcohol industry.[103] This highlights a bigger issue: defined behavioural risks and studies of behaviour change focus on individuals, but we are also concerned about the behaviour of whole organizations—businesses, governments, NGOs, religious institutions, and others.

Primary versus secondary prevention

Is it better to invest in protecting or improving health now or to risk illness and the possible failure of medical treatment in future? Is primary prevention (upstream) a better investment than secondary prevention (downstream)?

We can explore the pros and cons with an example that has been central to the history of public health—the slow and intermittent progress in achieving safe sanitation worldwide (Chapters 1 and 7). In the professional world of faecal management, the core of Figure 2.1 (in black) is called the F-diagram.[104,105] It maps out faecal-oral routes of infection—the pathways along which pathogens in animal and human faeces, including bacteria, viruses, and parasites, reach the mouths and guts of their human victims—through fluids, fingers, flies, fomites, fields, and floors.

The cardinal virtue of prevention, as compared with treatment, is the intent to avert entire episodes of illness, or at least episodes of serious illness. Interventions earlier in the causal chain (primary prevention, to the left of Figure 2.1) do this by blocking or removing environmental contamination through animal husbandry, fly control, water purification, sanitation, and drug treatment of infected humans and animals. Upstream interventions have costs and benefits beyond health: toilets can be designed to satisfy preferences, not only for cleanliness and hygiene, but also for convenience, dignity, privacy, and safety (in grey). A domestic sanitation system is a household asset, which not only disposes of excreta but can also recycle faecal waste in biofuels and fertilizers, add value to a property, and status to its owner.

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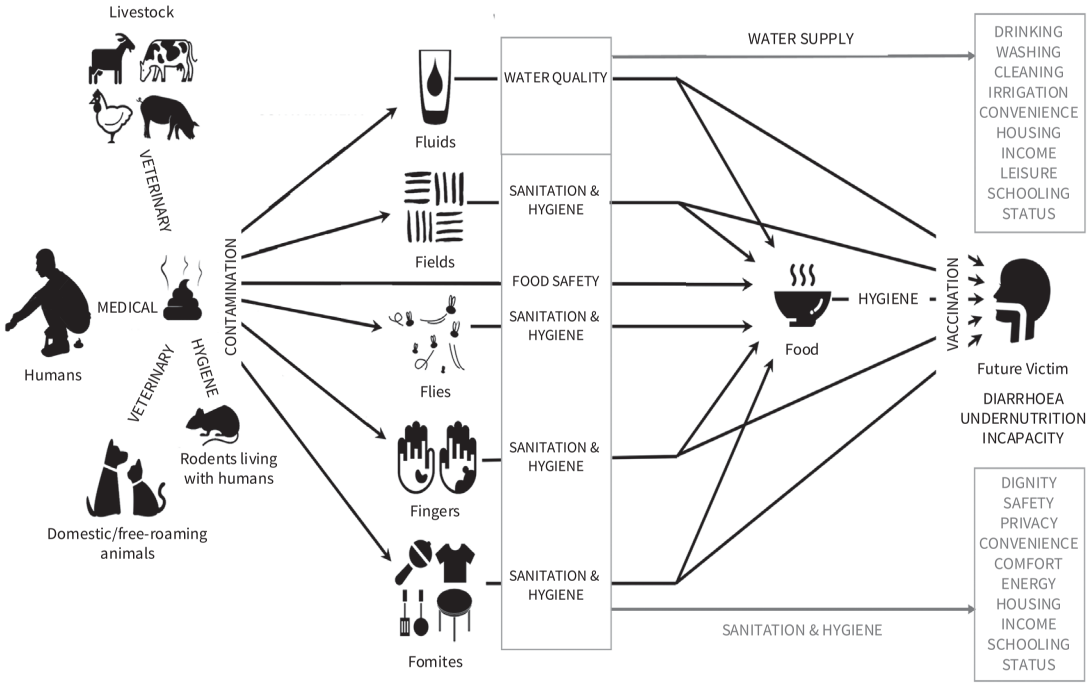

Figure 2.1 The F-diagram (black) of sources of intestinal infections acquired orally from human and animal faeces, and methods of blocking these sources of infection, expanded to include benefits other than health from safe water and sanitation (grey).

Adapted from Environ Sci Technol., 51(20), Penakalapati G, Swarthout J, Delahoy MJ, et al., Exposure to animal faeces and human health: a systematic review and proposed research priorities, pp. 11537–52, Copyright (2017), American Chemical Society. Reproduced under a Creative Commons Attribution License (CC BY 4.0).

Source: data from Hutton G, Chase C, Water supply, sanitation, and hygiene. In: Mock CN, Nugent R, Kobusingye O, et al., [eds], *Injury Prevention and Environmental Health*, pp. 171–98, Copyright (2017), International Bank for Reconstruction and Development/The World Bank.

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Water and sanitation infrastructure is costly; it delivers some health and financial returns quickly (installation of household toilets) and others slowly, over months and years (fewer pathogens in the environment). An immediate benefit has a higher present value than the same benefit delivered later.

Interventions further downstream (secondary prevention, to the right of Figure 2.1) have more specific, but more certain and more immediate health benefits. Better nutrition through breastfeeding, zinc supplements, and nutrient-rich food protects against diarrhoeal diseases and provides health benefits for children and their mothers.[106,107] Immunization can prevent infection with specific pathogens that cause diarrhoea—rotavirus, *Salmonella enterica* 'Typhi' (typhoid), *Vibrio* (cholera)—and helps to break the transmission cycle of these pathogens, but gives no protection against other causes of diarrhoea.[108-111]

Secondary prevention is sometimes more effective than primary prevention because it covers more sources of infection. For example, insecticide treated bed nets can prevent mosquito-borne infections, such as malaria and lymphatic filariasis, that are only partly due to failed sanitation (mosquitoes breed in a variety of water bodies, some outside sanitary systems). And food supplements can relieve malnutrition, whether or not the cause is linked to unsafe sanitation.

When all of these interventions fail to prevent illness (to the far right of Figure 2.1) then curative treatments are needed, such as oral rehydration therapy (ORT). ORT is a cheap, reliable, and rapidly effective remedy for diarrhoea caused by a variety of pathogens, but is underused and does little to interrupt onward transmission.[110,112,113]

This range of options makes clear the trade-offs up and down the causal chain of illness: primary prevention has a wider range of effects on costs and benefits for health, wellbeing, and the quality of life, but with less certain outcomes (more links in the chain, positive and negative), and acts relatively slowly.

Upstream actions that are designed to combat particular diseases tend to give fewer benefits per person treated: they capture more people who are at risk (high sensitivity) but include people who are not (low specificity). For those who are not at risk, preventive medical treatments carry the possibility of harmful side effects, which deters participation. The ideal population-wide intervention is one that has benefits everyone, such as the installation of a sanitary system (costs notwithstanding).

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If an intervention requires collaboration across disciplines and sectors, it may be harder to organize, demanding compromise among a diversity of collaborators—national government, local authorities, private companies, financing agencies, and householders, among others. This is a challenge for the implementation of all programmes that depend on cooperation—One Health, Health (or Prevention) in All Policies, and the Sustainable Development Goals (Chapters 1 and 3).

Secondary prevention tends to have narrower targets but more certain and more immediate outcomes. Downstream actions capture fewer people who are not at risk (high specificity) but miss some who are (low sensitivity).

In view of these trade-offs, costs and benefits are best judged with respect to particular interventions, rather than in terms of specific risks ('risk factors') or hazards to health (diseases). And because there are trade-offs up and down the causal chain of illness, there is likely to be an optimal point of intervention between primary and secondary prevention, where benefits are greatest in relation to costs.

Rose's 'paradox of prevention' (which is really a dilemma; Preface) makes the point. A large number of people exposed to a low risk could produce more cases than a small number of people exposed to a high risk. So the population-wide treatment of hypertension (high blood pressure), for example, brings large benefits to the community, maximally reducing deaths from coronary heart disease and stroke, but offers little, on average, to each person at low risk (Chapter 1).[114] This dilemma highlights a challenge for preventive health care, namely a mismatch of interests between hesitant patients (individuals) and all-inclusive health services (populations).

In the context of unsafe sanitation, the same applies to 'preventive chemotherapy' for intestinal nematode infections in children (mainly roundworm, hookworm, and whipworm).[115] The simplest and most effective approach is to treat all school-age children with benzimidazole drugs. The drugs are safe, but if the prevalence of infection is low, programmes will pay to treat many children unnecessarily. Setting a threshold prevalence of infection for mass treatment is less effective but more cost-effective. For a strategy with a lower threshold of 20% prevalence, a global programme costing $US 276m annually would spend 61% of funds treating infected children (in 2008). If the lower threshold is raised to 40% prevalence, the programme would cost less ($US 224m) and spend a larger percentage (78%) of the money treating infected children.[115] Armed with this information, the task is to balance

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effective and cost-effective strategies. The ultimate (more costly) solution is to improve sanitation and hygiene so as to remove all sources of infection (Chapter 7).

Whatever the choice of intervention, we need to know the full value of investing in water and sanitation, adding up all possible costs and benefits, inside and outside the health sector.[116] This is the same as making an Impact Inventory in cost-effectiveness analysis,[117] or carrying out a Full Value of Vaccines Assessment for immunization.[118,119] Analyses of prevention's immediate benefits sometimes neglect the longer-term consequences: for instance, a death averted is only a death postponed; saving a life now will incur medical costs later.

The F-diagram exposes one other factor that influences the point of intervention: contingency (Figure 2.1). It is a lucky coincidence, for instance, that rotavirus is a naturally immunizing infection, a factor that enables vaccine development. Or that *S.* Typhi, the agent of typhoid, has restricted routes of transmission that make this pathogen vulnerable to even modest improvements in sanitation. The reservoir for *S.* Typhi is exclusively human, the infectious dose is high compared with other pathogens that cause diarrhoea, and the sources are predominantly water and contaminated food, with little person-to-person transmission.

Finally, when there are options for both prevention and treatment, they are not usually simple alternatives (as framed by 'prevention is better than cure'). ORT should always be available as a treatment, even when most episodes of diarrhoea have been prevented. For diarrhoeal diseases, and for illnesses more generally, prevention is supplementary to cure, rather than an immediate replacement for it. Because medical treatment is always more urgent than prevention, extra resources have to be found for prevention in health services, until the need for treatment has been supplanted (Chapter 3).

Cooperation, competition, and conflict

We have so far considered costs and benefits for a single provider spending money on health, such as a government health department. And yet almost all means of improving health involve a transaction between two or more parties whose interests are not generally aligned. Health departments must frequently manage mismatches between service supply and public demand (Chapter 3). Promoting the consumption of alcohol, tobacco, and

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ultra-processed foods is profitable business for manufacturers, but the price for consumers of immediate pleasure is chronic harm (Chapter 6).

Economic evaluations, such as cost-effectiveness analysis, gloss over such differences, assuming that all viewpoints can be aggregated into a single outlook, usually labelled as 'healthcare sector' or 'societal' perspectives.[43]

The supply of, and demand for, preventive and curative care illustrate the challenge of advancing health by collective action. The demand for treatment of illness is usually greater than the demand for prevention. Essential treatment commands a higher price than cautionary prevention, and is relatively insensitive (less elastic) to increases in price. Patients facing rising health costs are more likely to forego, for example, routine diabetic screening than surgery for acute appendicitis.[120] So pushing up the cost of prevention and treatment tends to widen the gap between the two.

Competition and cooperation can also be complementary, in sequence. The initial spread of an innovation commonly depends on outperforming competitors in a market. But the balance between supply and demand in a market does not guarantee supply for everyone. So governments, as agents of collective action, are usually needed to make a winning innovation available for everyone, including those who cannot pay for it—to correct 'market failure' in pursuit of Universal Health Coverage.

Public and private goods

It is often said that prevention is at a disadvantage because it is a public good: in any population, some individuals are less willing than others to pay for a service that is available to everyone. They judge that paying taxes for public goods is poor value for their money, or they simply prefer to 'free ride' on communal amenities. In fact, both prevention and curative treatment can be public or private goods. The distinction between types of goods influences who is willing to pay for them and who is willing to supply them, often with major consequences for personal and public health.

Public goods are non-excludable and non-rivalrous (or non-subtractable); that is, no one can be prevented from using them and consumption by one person does not reduce the quantity available for others. Public goods are normally provided and paid for by collective action; a government should be able to provide them on behalf of a society that is willing to pay for them. Public goods that prevent illness or injury include clean air

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and speed limits on roads. Among those that support medical treatment are scientific knowledge, health care data, medical regulatory systems, and the peace of mind that comes from knowing a health service is there if needed.

Private goods are excludable and rivalrous. They include personal protective equipment (gowns and masks for infection control), preventive medications (drugs that lower blood pressure or cholesterol), vaccines and health insurance when these are available to some people and not others, and in limited supply. Merit goods are also private goods that have benefits to society at large, such as vaccines that prevent the transmission of infection (an 'externality') in addition to preventing the acquisition of infection.

Common goods are non-excludable but rivalrous; without the ownership that would encourage maintenance of a resource, they are vulnerable to competitive depletion—the 'tragedy of the commons'.[121] Examples are overgrazing by livestock on common land, overfishing in open-access waters, and depletion of the finite global carbon budget that keeps global warming within safe limits (Chapter 8). The UK National Health Service is a common good rather than a public good: the NHS provides free care for all at the point of delivery but finite resources mean that people must compete for access, as made plain by the long waiting lists for treatment in 2023–4.

Club goods are excludable but non-rivalrous. Private health services are essentially clubs when they offer prevention and treatment facilities to anyone who can afford them. By excluding those who cannot, private health services could be an obstacle to achieving Universal Health Coverage (another market failure).

Promotion and prevention in practice

What do health promotion and disease prevention cost today and what are the benefits? According to analyses based on the International System of Health Accounts (SHA, Box 2.2), only 2–4% of the US$ 9 trillion spent on health in 2019 was allocated to prevention and public health while 94% spent on inpatient and outpatient services, medical goods (mainly pharmaceuticals), and long-term care (Preface).[122] But this analysis does not reflect the true investment in prevention globally, for at least two reasons. First, some spending on prevention is integrated into curative care services, especially in high-income countries. Second, and more important, SHA counts only spending that has direct benefits for health; it omits spending outside

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the health sector which contributes indirectly to, and in turn benefits from, good health.

There have been few attempts to track spending on health and for health—evaluating the full costs and benefits—outside the health sector. However, an analysis of global trends in disease incidence and mortality rates indicates that spending which benefits prevention rather than cure is far greater than represented by the 2–4% reported by SHA. Figure 2.2 shows that per capita mortality and incidence rates due to 115 health conditions were mostly in decline between 1990 and 2019 (though the total numbers of cases and deaths for many conditions increased over that period). The points on the graph lie mainly in the lower left quadrant (60/115); to the left of the vertical line for mortality only (92/115), and below the horizontal line for incidence only (65/115).

For the 60 conditions where both incidence and mortality rates were in decline, the proportional reduction in the incidence rate was on average 50% (interquartile range 34–82%) of the proportional reduction in the mortality rate. In other words, half of the reduction in mortality was due to prevention rather than to the treatment of illness.

Figure 2.2 shows that successes in primary prevention between 1990 and 2019 go far beyond those indicated by health accounts (the 2–4% in SHA). But this analysis actually understates the contribution of prevention to health by excluding secondary prevention (after the early onset of illness), vaccine-preventable epidemics and pandemics (COVID-19 and others), and conditions that are rarely fatal (such as common fungal skin diseases, leprosy, and lower back pain).

In the past three decades, multiple successful, population-wide interventions have reduced the incidence (prevention) of conditions that have a few major, modifiable 'risk factors'—including coronary or ischaemic heart disease (high total blood cholesterol, high blood pressure, tobacco smoking),[123,124] and vaccine-preventable,[125] vector-borne[126] and other transmissible infections (prevention: points that lie along the diagonal in Figure 2.2). In contrast, successful interventions against conditions with multiple or unpreventable causes are mostly treatments that reduce mortality, such as congenital birth defects, diarrhoeal diseases, road injuries and upper respiratory infections (cure: points lying along the horizontal line in Figure 2.2). Most of these interventions are funded partly within and partly outside the health sector, so SHA understates the total costs.

Although the details of studies on specific health conditions may differ from the picture in Figure 2.2, it is clear that prevention, even with biological

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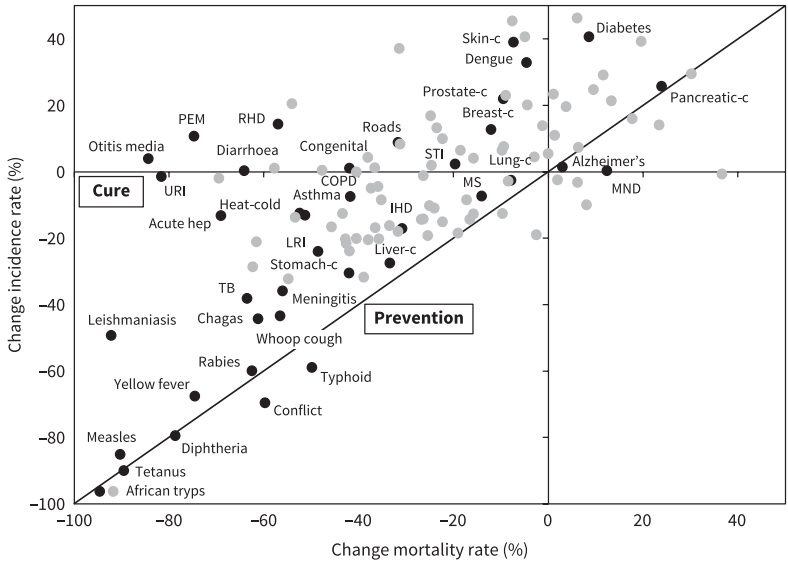

Figure 2.2 Health gains from prevention and curative treatment over three decades, 1990–2019. Percentage change in per capita, age-standardized case incidence, and mortality rates, for 115 health conditions that accounted for >90% of deaths in 2019 (selectively labelled). Successful interventions against conditions with multiple or unpreventable causes are mostly due to treatments that reduce mortality (points lie along the horizontal). Prevention is dominant when targeting one or a few major, modifiable 'risk factors' for illness or injury (points lie along the diagonal). Abbreviations for labelled points (black): Alzheimer's disease and other dementias, IHD ischaemic heart disease, LRI and URI lower and upper respiratory infections, MND motor neurone disease, PEM protein energy malnutrition, RHD rheumatic heart disease, Road injuries, STI sexually transmitted infections, TB tuberculosis, suffix c cancer.

Source: analysis based on published estimates of incidence and mortality. Data from Institute for Health Metrics and Evaluation (IHME), GBD Results Tool, Copyright (2023), University of Washington. Available at http://ghdx.healthdata.org/gbd-results-tool (accessed 10 March 2021).

and technological constraints, has improved public health. The incidence rate of illness has been reduced, especially through targeted interventions against major risks and hazards.

All these preventive methods, plus curative ones, have contributed to the continuing rise in life expectancy from birth around the world, from

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65 to 73 years over the period 1990 to 2019 (pre-COVID-19), even though targets for sustainable development have been missed. Healthy life expectancy (HALE) increased from 57 to 64 years over the same period, although life expectancy dropped by about two years during COVID-19 pandemic, 2019–21.

In the long term (more than three decades), the success of prevention depends not just on targeted interventions, but also on the less controllable circumstances of social and economic development. Figure 2.3 shows the fates of four different causes of illness and death.[127] Although vaccines are available to prevent lower respiratory infections (LRI e.g. pneumococcal pneumonia, influenza), the short-term solutions to managing (bacterial) pneumonia are mainly antibiotic treatment and clinical care to accelerate recovery and prevent death (Figure 2.2). But over decades of development (as countries acquire a higher socio-demographic index, SDI) the incidence of illness caused by respiratory infections has fallen alongside deaths (Figure 2.3(a)).

Pneumonia is linked to numerous facets of poverty: the implication is that multiple effects of development are needed to lower the incidence of LRI: healthier environments (less exposure to infection), better medical services (higher vaccination rates), and healthier people (greater resistance to infection). The same is true of the multiple causes of diarrhoeal diseases (a variety of pathogens), but deaths are negligible in countries with high-middle and high SDI (Figure 2.3(b)). Typhoid is an exception among diarrhoeal diseases: prevention has been relatively effective because *S.* Typhi, with its restricted routes of transmission (as described above), is especially vulnerable to improvements in sanitation and hygiene (Figure 2.2).

Type 2 diabetes is a metabolic disease with multiple effects on the heart, kidneys and other organs that can be prevented by reducing body weight, increasing physical activity, and switching to a diet low in saturated fat and high in fibre.[128] Despite the effectiveness of lifestyle changes, type 2 diabetes has become a global health emergency: incidence is high at all levels of SDI; only mortality has been significantly reduced, and in countries with higher levels of development (Figure 2.3(c)). In 2021, more than 500 million adults (20–79 years) worldwide were living with diabetes (mostly type 2) and, on present trends, around 800 million will do so by 2045.[129]

Cancers of the trachea, bronchus, and lung are caused mainly by cigarette smoking, but control programmes still face a huge task in reversing the adverse effects of tobacco consumption linked to social and economic development. The incidence of these cancers is highest in countries with

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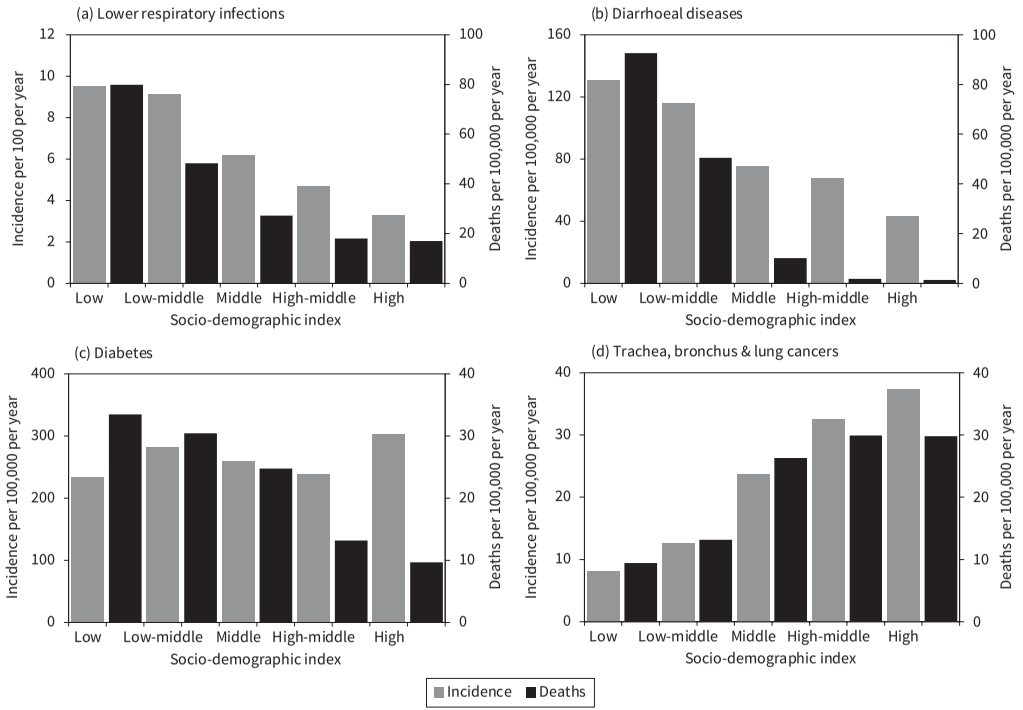

Figure 2.3 Long-term gains and losses from prevention and curative treatment worldwide: four examples using a socio-demographic index as a measure of development running over decades. (a) lower respiratory infections, (b) diarrhoeal diseases, (c) diabetes, (d) cancers of trachea, bronchus, and lung.

Source: analysis based on published estimates of age-standardized incidence and mortality rates for 2019. Data from Institute for Health Metrics and Evaluation (IHME), GBD Compare—Viz Hub, Copyright (2020), University of Washington. Available at https://vizhub.healthdata.org/gbd-compare/ (accessed 10 March 2021).

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middle and high SDI where, despite tobacco cessation measures, smoking is still widespread (Figure 2.3(d); Chapter 6). Like lung cancer, the per capita incidence of road injuries has increased greatly with development, though road deaths have not (not shown in Figure 2.3). In countries with higher SDI, more roads and cars lead to more accidents, but the accidents are less deadly because the roads and cars are safer.

Three conclusions emerge from this mixed picture of health in development. First, diverging health trends during development means that distinct health challenges still need distinct solutions, from diabetes to road safety. Second, social and economic advances are largely a force for good but the full benefits come from 'Prevention in All Policies'; that is, coordinated action across government ministries for education, environment, income, and social protection, alongside health ministries and the private sector.[130] This is the work of years or decades (as in Figure 2.3), and will continue far beyond the timetable set by the 2030 Sustainable Development Agenda. Third, although boosting national economies (and otherwise improving societies) is not a practical, short-term plan for better health, targeted interventions are sometimes effective. As an example, increases in household income can, where there is a will to deploy them, yield relatively rapid health benefits through tax credits, conditional cash transfers, health insurance, or through specific local initiatives such as enabling people to live in higher-income neighbourhoods.[131-133]

This overview of the principles and practice offers a checklist of ways to protect and improve health. Chapters 3–8 investigate how these methods can be applied in six different settings—from prevention in health services to adaptation in the face of climate change.

Summary

Most people aspire to healthy living but protecting and improving health carry a cost—counted in money, effort, information, time, trust, and willpower. The wisdom of foresight can be framed as a conditional hypothesis: protecting and improving health are more likely to be favoured when individuals or populations can choose a low-cost method of averting, rapidly and certainly, a large threat to health, or of gaining a large benefit for health. The decisions that people make about health depend, not just on measurable hazards, risks, and time scales but also on the subjective values of everyone who has a stake in the outcome—individuals, governments,

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NGOs, businesses, and others. Prevention has been much more successful than reported through national health accounts—in the short term through targeted interventions against major risks and hazards, and in the long term through social and economic development. But the enormous, persistent, avoidable burden of ill-health is reason to make a persuasive case for investing still more.

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3
Preventive care

An affordable dream?

> A rebalancing of policy away from health care to health . . . will not happen until there is a realignment of incentives in the system
>
> **Derek Wanless (*Securing Good Health for the Whole Population* (2004)[1]**

Universal Health Coverage (UHC) is Amartya Sen's 'affordable dream'.[2] The dream is that everyone has access to the health services they need without the risk of financial hardship. That means promoting and protecting public health, as well as providing medical care for individual patients. The 'universal' is intended to make UHC a force for equity in sustainable development—'to ensure that no one is left behind'.[3]

In addressing both the immediate and underlying causes of illness, health promotion and disease prevention (together called 'preventive care' in this chapter) compete for resources within the health sector and with other sectors of government. In both competitions, the argument for good health starts from a comparatively weak position. This is because, in practice, the main function of a health service is to cure illness—medicine is the priority, public health is a supporting act. Outside the health sector, health is a by-product of activities that have other goals and priorities—the economy, education, energy, environment, and so on.

This chapter focuses on one-half of the problem: how to strengthen preventive care within health services (Chapters 6–8 examine the other half; Chapters 4 and 5 look at specific examples). The main preventive tools available to health services are vaccination; mitigation of behavioural,

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environmental, and occupational risks; information, education, and promotion; screening and early detection of illness; and chronic disease management (Box 2.2). The question here is whether using these tools to keep people healthy—by supplying health services and facilitating demand for them—is an affordable part of UHC.

The answer goes beyond analyses of the cost and cost-effectiveness of health services because preventive care needs more than a menu of generic 'best buys' from economic evaluation. Arguments for prevention as part of UHC must begin with an understanding of why health services (which are mainly sickness services) exist. Put simply, everyone knows they will need medical treatment sooner or later, but they cannot predict what and when illnesses or injuries will befall them. The inevitability of illness, but the uncertainty about what and when, suggests that many people should be willing to buy insurance to pool risks and share costs. Not everyone will be inclined to do so (e.g. those who are young, healthy, and poor); so mandatory, population-wide, pre-paid, all-illness health insurance is most compatible with the goals of UHC.

Whether an all-illness service includes preventive care depends partly on how members of the public perceive the future risk of illness. A national health service sees patients' futures play out every day—the population sum of the lifelong risk of illness. Could health services, in collaboration with the public, anticipate and reduce those risks through preventive care at tolerable extra cost?

The question of affordability concerns both rich and poor countries in different ways. The former are managing the high costs of advanced medical care while the latter are struggling to build essential health services. In both cases, the solutions proposed here put preventive care at the heart of primary healthcare.

Affordability is about the amount of money, but it is also about the way money is raised and spent. In particular, health promotion and disease prevention will never take priority over urgent medical care, so additional, protected investment is needed first to supplement, but eventually to supplant, the treatment of illness.

Promotion, prevention, and Universal Health Coverage

UHC is a political project in which technical means are used to reach societal goals expressed, for example, in the WHO Constitution (1948) and

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propagated by the Alma-Ata Declaration (1978) and WHO's strategy of Health For All (1981). Sen argued that basic healthcare is affordable for everyone, even in low-income countries, reinforcing messages in the Rockefeller Foundation's *Good Health at Low Cost (1985*) and the World Bank's *Investing in Health (1993).*

He made his own case by pointing to the low costs and large, equitable benefits of public health and medical services in Costa Rica, Kerala (India), Rwanda, Sri Lanka, and Thailand. He compared public with private healthcare in these countries and elsewhere, viewing private care as exploitative, overpriced, and inefficient. He identified some of the reasons why health services should be universal, for example contagious diseases are best controlled by protecting populations as well as individuals. And he listed some of the means, such as giving women key roles in the delivery of health and education. However, to replicate the achievements of countries like Costa Rica needs a deeper analysis of how to reach such ambitious goals.

Sen's exemplary settings might be generalizable models or they might be exceptions that prove a rule. Each of his chosen countries is travelling a different route to achieve UHC. Costa Rica established a parliamentary democracy in the early twentieth century and avoided military rule (unlike some neighbouring Latin American states).[4] Primary healthcare, emphasizing health promotion and disease prevention, was strengthened during the 1990s and health is now aligned with congruent societal aims, including sustainable forestry and environmental protection.[5,6] In Kerala, a shared identity between different ethnic groups—a sense of 'we-ness'—has bred progressive social policy for more than a century and underpins the drive for UHC today.[7] Rwanda emerged from genocide in 1994 with an autocratic government that happens to favour public health as an instrument of social cohesion.[8]

Social context determines what health services can provide in richer as well as poorer countries. One of the lessons of Finland's huge success in reducing deaths from cardiovascular disease is that understanding local epidemiology and the sense of community are as critical as the technicalities of a health intervention. In 1969, the North Karelia region of Finland had, from the perspective of public health, a very high incidence of heart disease; the annual death rate was 690 per 100,000 men aged 35–64 years. The goal was to reduce heart disease by discouraging tobacco smoking, and by promoting diets low in saturated fat and salt, and high in fruit and vegetables. That needed community-wide collaboration, involving agriculture and food industries, citizen's organizations, and the general public, legislators,

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and the media. Part of the reason, perhaps, why this initiative had to involve everyone is that the risk of death to anyone was very low—only 0.69% annually for each man. This model intervention cut serum cholesterol levels, hypertension, and smoking prevalence and, by 2011, mortality from cardiovascular disease had fallen by 85%, to 100 per 100 000 men aged 35–64 years. About two-thirds of the reduction was attributable to the lowering of risk factors, especially serum cholesterol.[9,10]

The possibilities and the approach to health and welfare taken by governments are influenced by public inclinations towards reciprocity and the redistribution of wealth, and towards individual and collective action.[11] Among OECD countries, redistribution is relatively high in France, Poland, and Spain. In contrast, Japan, the UK, and the US put greater emphasis on market competition, which is less conducive to public health.[12] Austria, Germany, and Norway lie in between. The 'moral economies' of all these countries find a place for welfare, and more so as they have become wealthier over the past century[13] but, crucially, with different motives for social investment: to enable social contribution in Germany, to promote equality and mobility in Norway, and to encourage personal responsibility in the UK.[14]

The success of public health policy depends on understanding and making use of these motives. In Britain's post-1945 combat against William Beveridge's 'five giants'—want, ignorance, disease, squalor, and idleness (in other words, income, education, health, housing, and employment), the National Health Service (NHS) was just one part of a vision of social reconstruction and progress. Without stifling incentives, opportunities, and responsibilities, Beveridge foresaw a nation with a common purpose: 'Freedom from want cannot be forced on a democracy or given to a democracy. It must be won by them. Winning it needs . . . a sense of national unity'.[15,16] Created in 1948 by Health Minister Aneurin Bevan, the NHS stood 'in place of fear' as an inclusive, nationwide insurance policy for health.

The question of how to fund healthcare in the UK has frequently been revisited over the 75 years since Bevan and Beveridge. The 2004 Wanless report on *Securing Good Health for the Whole Population*[1] drew conclusions that are still relevant today, and which apply beyond the UK context:

> Numerous policy statements and initiatives in the field of public health have not resulted in a rebalancing of policy away from healthcare (a 'national sickness service') to health (a 'national health service'). This will

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> not happen until there is a realignment of incentives in the system to focus on reducing the burden of disease and tackling the key lifestyle and environmental risks. Reducing the burden of disease . . . needs a clear articulation of the priorities for action with accountabilities defined both within and outside of the National Health Service.

In 2023, the rebalancing and realignment have still not happened, and opinion about how best to provide healthcare in the UK remains divided. Some see the NHS and its role in public health as a flagship of social democracy. Others believe that publicly funded healthcare encourages irresponsible dependency, whereas private healthcare stimulates self-reliance and freedom of choice. Current pressures on the NHS, plus a permissive political milieu, are recreating the heterogeneous health service of the 1930s—with more profit-driven private healthcare and reduced access to public services, unevenly remedied by a patchwork of community initiatives.[17]

Taking up the Wanless challenge, the rest of this chapter explores ways to navigate the obstacles and magnify the incentives for preventive care within health services, not just in the UK but around the world.

Is preventive care affordable?

Economic evaluations have repeatedly concluded that prevention is good value for money (Preface). Global trends in health expenditure suggest that prevention should be affordable for two further reasons.

First, wealthier nations spend more on health—in total, per person, and as a share of Gross Domestic Product (GDP) (Figure 3.1(a), black). However, as health budgets grow larger over years and decades of economic development, an ever-smaller fraction of health spending is allocated to prevention (Figure 3.1(a), grey), falling from as much as 30% in some low-income countries to less than 5% in high-income countries (Figure 3.1(b), black; Chapter 2). The same is true of spending on primary healthcare, including prevention, which accounts for less than half of all health expenditure in most high-income countries (Figure 3.1(b), grey). In view of the large health expenditures in high-income countries, boosting the much smaller budgets for prevention (above 5%) would add little to health spending overall.

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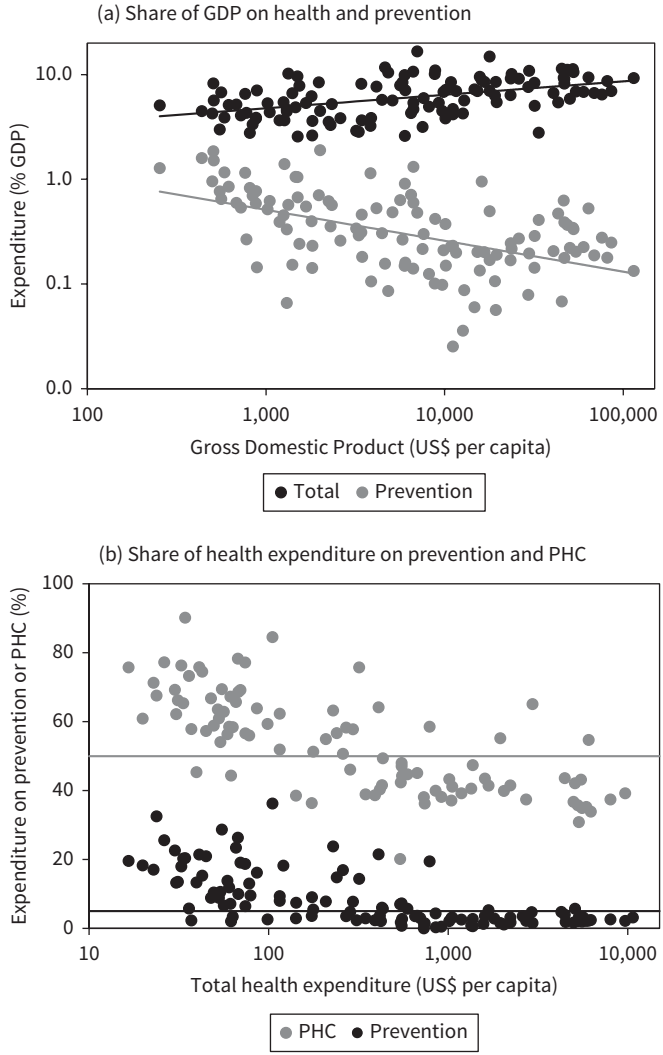

Figure 3.1 Is preventive care affordable? (a) National expenditure (per person) on health as a percentage of GDP, in total (black) and for prevention (grey). Total health spending increases faster than GDP (positive gradient) but spending on prevention increases more slowly (negative gradient). Consequently, (b) in high-income countries, where health expenditure is greater, prevention (black) forms a smaller percentage of health spending overall, mostly less than 5% (black line). Likewise, spending on primary healthcare (PHC) forms a smaller percentage of GDP in high-income countries, mostly less than 50% (grey line).

Source: data from World Health Organization, Global Health Expenditure Database, Copyright (2023). Available at https://apps.who.int/nha/database (accessed 15 March 2023).

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Second, as health expenditure grows faster than GDP, especially in high-income countries (Figure 3.2), there is greater pressure to keep medical costs down through prevention.[18] Healthcare is disproportionately costly in rich countries because people are willing and able to spend more on hospitals and advanced medical devices, on medicines and medical insurance, and on high salaries and fees for medical specialists.[19,20] A signal of the trend in the UK is the increasing ratio of consultants to general practitioners, favouring secondary over primary healthcare. There is high demand for medical treatment by people when they become ill, and relatively low demand for preventive care while they are healthy. The demand-driven costs of treatment are becoming an unaffordable medical surcharge on health. There is an obvious if partial solution: high treatment costs can be offset by greater investment in prevention.[18]

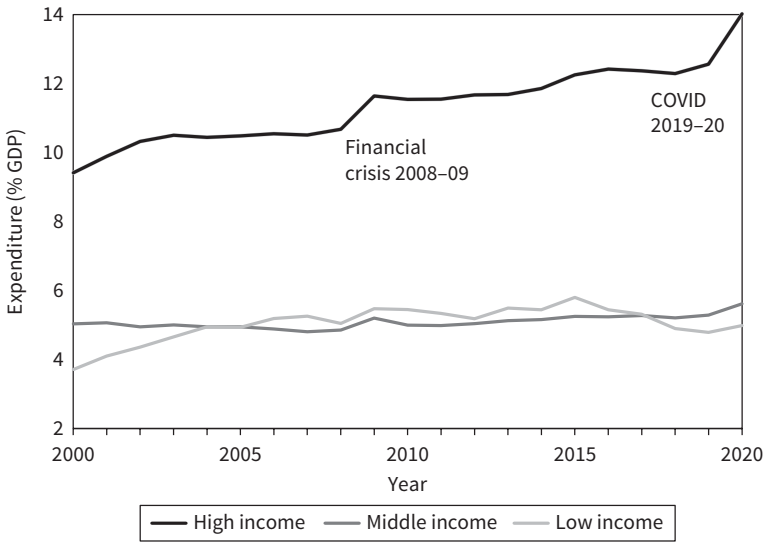

Figure 3.2 Trends in health expenditure as a percentage of GDP in low-, middle-, and high-income countries, between 2000 and 2020. The cost of healthcare is relatively high and mounting in high-income countries. The global financial crisis in 2008–9 reduced GDP, and COVID-19 pushed up health expenditure; both were most evident in high-income countries.

Source: data from World Bank, World Development Indicators, Copyright (2023). Available at https://databank.worldbank.org/source/world-development-indicators (accessed July 11 2023).

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These two complementary forces—the relatively low cost of prevention and the high cost of treatment—favour investment in prevention. But there are other obstacles to navigate, which are intrinsic to health systems and the social context in which they operate. They are first, prevention is usually a lower priority than the treatment of illness, especially during emergencies. Second, affordability applies to patient demand as well as health service supply, and there is lower demand for prevention than for treatment. Third, one person's expenditure (patients and the public) is another person's income (physicians and pharmacies), so we can expect resistance to the idea of cutting medical costs. Fourth, health spending is normally restricted to services that directly benefit health, so preventive care that begins earlier in the causal chain needs collaboration with other sectors. Finally, prevention is often a focal point in political debate about individual and state responsibilities for health (see also 'nanny states' in Chapter 6). The next three sections consider the role of prevention in routine and emergency healthcare, before proposing some solutions.

Prevention is ancillary to cure

When resources are limited, medical treatment of the sick always takes priority over preventive care for the healthy. Triage is sensible and inevitable, but sickness also yields to 'the rule of rescue, enabling the instant saving of otherwise doomed lives'.[21] There is drama in an emergency, in addition to immediate need.[22] Consequently, preventive care needs an additional, protected budget. Any proposed reallocation of funds from treatment to prevention, while treatment remains a priority, is unlikely to be practical.[23] In addition, excellent medical services present a possible moral hazard—if people are confident of receiving the clinical care they need when they fall sick (with any kind of illness), why go to the effort of prevention (of selected causes of illness, which anyway might not happen)?

Public health services should take a different view. Extra spending on prevention, from a ringfenced budget, promises multiplicative returns. When the cost of treatment eventually falls as fewer people become ill, the savings could be spent more efficiently on prevention, which then saves even more money on treatment, and so on. Conceptually at least, this kind of positive feedback would be a push towards more effective health services (UHC) and towards better health.

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Prevention during emergencies

Prevention is usually one of the first casualties of an emergency. After the 2007–8 financial crisis, the fall in GDP growth in OECD countries was followed by a bigger reduction in spending on prevention than on health in total.[24-26] At that time, prevention and public health were particularly vulnerable to funding cuts in England, France, Moldova, the Netherlands, and Slovenia.[25] The financial crisis of 2007–8 had a greater impact on health than the 2009 H1N1 'swine flu' pandemic, the first ever (of six) designated public health emergency of international concern (PHEIC; Chapter 4).

In the UK, the handicap faced by prevention and public health has persisted well beyond the 2007–8 economic downturn. Under a Conservative government hostile to funding public services, per capita spending overall on the NHS grew more slowly (1.2% in 2022/23) than the long-term average (3.6%/year since 1948). The public health grant was cut by 26% between 2015/16 and 2022/23,[27] leaving fewer resources to help people manage alcohol and tobacco consumption, poor diets, and low physical activity, and for sexual health services. Diminished funding for public health means that opportunities for early intervention are missed, leading to the predictable increase of preventable illnesses in an ageing population—blindness, diabetes, cancers, chronic obstructive pulmonary disease, heart disease, chronic pain, and reduced mobility, among others.[28] But younger people are affected too; advanced tooth decay in children is strongly associated with the consumption of sugar-sweetened food and drinks, with social and economic deprivation, and with failed prevention strategies.[29-31]

Persistently low spending on the NHS and on public health risks pushing the UK into a sickness trap: when more money is urgently needed to catch up on NHS funding, governments are inclined to raid the public health grant.[32] Less prevention leads to more illness, for which the NHS needs even more resources, putting yet more pressure on funds for public health.

UK government policy papers have illuminated the chasm between scientific understanding and political rhetoric on prevention.[33,34] However, forces for greater investment in prevention and public health are at work, albeit slowly. England's Chief Medical Officer has called for the restoration of prevention in the NHS.[35] And, since 2010, a growing number of people in the UK have said they are ready to pay higher taxes to spend more on health, education, and social benefits.[36] That readiness may be tested by the Labour government that took office on 5 July 2024 (as this book went to press).

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Public health budgets are difficult to defend, in part because the adverse effects of cuts are hard to measure precisely. And the difficulties of determining the contributing and underlying causes of a death (as well as the immediate cause) also limit accountability—no one will be held responsible. Nevertheless, it is clear that austerity—imposed by tightening the reins on government spending—is deadly. In England, a series of research studies concluded that the failure to maintain investment in health and social care caused between 131,000 and 335,000 preventable deaths between 2012 and 2022 (excluding deaths from COVID-19).[37-40] These excess (preventable) deaths occurred across all age groups, not just the elderly, and they were closely linked to deprivation.[40] Among them are 'deaths of despair' from drugs, suicides, accidents, and alcohol, which are exceptionally high in Scotland.[41] More than a decade of austerity in the UK—a political choice, arguably not an economic necessity—cost hundreds of thousands of lives and slowed improvements in health, especially affecting the poor.

In the US, as in the UK, the public health disadvantage has deeper roots than the 2007–8 financial crisis—public health's share of all health spending in the US increased from 1.4% in 1960 to a peak of 3.2% in 2002, but has since fallen back to 2.8% in 2019 (before COVID-19).[42,43] The roots lie in political (and even medical) opposition to Universal Health Coverage, especially the idea of pre-payment for public health services by compulsory taxation or insurance, which is an efficient funding formula for UHC.[44,45]

The squeeze on prevention and public health budgets is visible in state and local governments too, which are the main source of public health dollars in the US. For instance, the rising cost of medical care in California has put enormous pressure on funds for other services including public education, public health, food and housing assistance, and income support. In 2007, spending on public health, the environment, and social services was US$1.22 for every dollar spent on medical care, but had dropped to just US$0.68 by 2018.[46]

COVID-19, however, had a different effect, out of necessity. When the economic hardship is due to a health crisis that demands preventive care—such as vaccination during a pandemic—the budget for prevention rises, at least temporarily. Globally, spending on prevention rose by about one-third in 2020 due to COVID-19, providing more money for diagnostic testing and surveillance, and launching the first immunization programmes (vaccines became widely available in 2021).[47] The uptick in funding was more visible in high-income countries because they had more money to cover the extra costs (Figure 3.2).

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Despite the surge in expenditure due to COVID-19, the greatest beneficiaries of vaccination and other forms of preventive care were wealthier people living in high-income countries. In the push for UHC, mass vaccination has the potential to improve equity in healthcare. Globally, it has not done so because of vaccine nationalism (politicians are responsible first for their own electorates), commercial imperatives (pharmaceutical companies are obliged to maximize returns on investment), and limited manufacturing capacity (most countries have neither plants nor licences to make their own vaccines).[48,49] Unlike other catastrophic plagues, COVID-19 did not become one of society's *Great Levelers*.[50]

Demand as well as supply

Before the COVID-19 pandemic, the world's public health services were a long way short of global targets for UHC. The aggregate global UHC index increased from 45 in 2000 to 67 in 2019 (out of 100). In 2017, between 1.4 and 1.9 billion people worldwide faced catastrophic (more than 10% of a household budget spent on health) or impoverishing health spending (pushing a household below a relative poverty line), and there were large inequalities in service coverage and financial hardship for patients within and between countries. COVID-19 made slow progress to UHC even slower, disrupting essential services in more than 90% of countries and increasing the risk of catastrophic costs to households.[51,52] Moreover, many low- and middle-income countries are paralysed by debt, which threatens spending on public services, such as health and education. The critical point is that, if governments and the people they serve cannot afford basic medical care for sickness, they are unlikely to invest in prevention, which is a lower priority.

UHC means that everyone has access to the health services they need without risk of financial hardship. Figure 3.3 summarizes regional progress to UHC along those two dimensions of supply and demand—service coverage and financial protection. The majority of 14 service coverage indicators that contribute to the aggregate coverage index are for necessary preventive care, including family planning, immunization, sanitation, and managing risk factors for chronic disease.[51] Prevention is therefore a prerequisite for UHC.

All regions and countries are aiming for Quadrant I – high levels of service coverage and low levels of catastrophic health spending. In 2017, only

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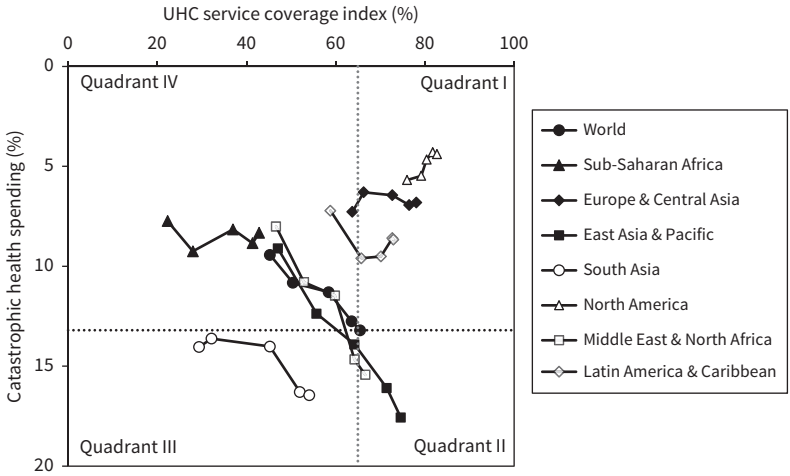

Figure 3.3 Health service supply and demand worldwide and in seven regions, 2000–17, in terms of two SDG indicators: the aggregate coverage of 14 sentinel services (horizontal axis) and the prevalence of catastrophic out-of-pocket health spending (% population spending >10% of household consumption or income on healthcare; vertical axis, reverse scale). All regions (as defined by the World Bank) improved coverage between 2000 and 2017 (left to right, points mark successive years) but catastrophic health spending increased in some regions when the expansion of services outstripped the ability to access or pay for them. Quadrants are defined by global averages of the two metrics in 2017.

Source: data from World Health Organization and International Bank for Reconstruction and Development/The World Bank, Tracking Universal Health Coverage: 2021 global monitoring report, Copyright (2021), World Health Organization; World Bank, Universal Health Coverage Global Monitoring Data—2021. 18 January 2023, Copyright (2023). Available at https://datacatalog.worldbank.org/search/dataset/0060802 (accessed 5 July 2023).

North America, Latin America & Caribbean and Europe & Central Asia had achieved that goal.

Quadrant II includes regions that have expanded health service coverage but, in doing so, increased the incidence of catastrophic health spending. China is the main driver of trends in the East Asia and Pacific region, and illustrates the challenges of matching health service supply with public demand. Based on China's experience, protecting people from catastrophic health spending needs strong primary healthcare including prevention; sufficient capacity in primary care to avoid spillover to costly private

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practitioners; comprehensive not partial insurance coverage, avoiding deductibles, copayments, or caps on reimbursement; and ways to avoid the use of unduly expensive procedures and medication.[51] Even without these features, UHC service coverage increases faster than catastrophic health spending, indicating that there has been a net benefit (Figure 3.3).

The Middle East and North Africa is heading in the same direction as East Asia (Quadrant II). Sub-Saharan Africa could follow as coverage expands (Quadrant IV). In 2017, South Asia was in the least favourable position, with low service coverage and a high frequency of ruinous personal spending on health (Quadrant III).

In India, South Asia's most populous country, the drive to achieve UHC by 2030 is partly through the expansion of much needed but underfunded primary health centres. A popular health insurance scheme provides financial protection (a component of Ayushman Bharat, Healthy India) but for hospital care only, pushing public spending towards treatment and away from prevention. Seventy per cent of medical consultations in India are with private practitioners who are largely unregulated, often unqualified, and who operate mainly in towns and cities. An estimated 62% of payments are made out-of-pocket and there is practically no insurance for outpatient care. Under these circumstances, prevention and early disease diagnosis are distant aspirations for most people in India.[53]

The frequency of out-of-pocket and uninsured health spending in India is part of a general phenomenon—most primary healthcare around the world is obtained by private spending on outpatient consultations and medicines.[19,54] Day-to-day healthcare for most people in most countries is precarious. As one example, when malaria prevention (by insecticide-treated nets or indoor insecticidal sprays) fails, people with malaria symptoms but without health insurance have to buy anti-malarial drugs in pharmacies. If symptoms progress to serious illness, they may have to pay for hospital treatment too. Costs that were merely burdensome at first can then become catastrophic. One systematic review found that approximately 1 in 5 households (about 20%) surveyed in Mozambique, Sudan, and Zimbabwe (4 studies, range 18–23%) had suffered catastrophic health spending due to malaria.[55]

Preventive care in low-income countries typically receives a substantial, protected budget only under special circumstances, notably when foreign aid funds specific programmes, such as those for immunization and nutrition (see 'Global health' below).[19]

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Making the case for preventive care

As proposed by Wanless and his successors,[1,56] the most persuasive arguments for preventive care are based on incentives for supply and demand. The following sections illustrate some of these incentives, and show how and why they work at global, national, and local levels. They also show how, on these different scales, prevention can be aided by efficiency, technology, measurement, and partnership.

Global health: campaigns for prevention

Global health initiatives (GHIs) work best for interventions that are known to be effective, and which target vulnerable people at high risk in low-income countries. Or when investment is needed to contain emerging international health threats. The most effective GHIs—which give large and clear returns on investment by donors—include the US President's Emergency Plan for AIDS Relief (PEPFAR), the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM), the Global Polio Eradication Initiative (GPEI), and the GAVI Alliance for vaccination.

Funding for GAVI, in particular, is driven by a simple and compelling argument: vaccines save lives. Vaccination has been among the most successful forms of prevention in history (Chapter 2), and the best vaccines have all the characteristics of ideal preventive tools: they immunize against specific and serious hazards (notably to children), with a high chance of success (efficacy) on short timescales and at low cost. While smallpox eradication was a landmark in global public health, and polio may follow shortly, the greatest impact of immunization has been through routine vaccination by health services, especially via WHO's Essential Programme on Immunization (Chapter 1).[57] Full implementation of the Immunization Agenda 2030, vaccinating against 14 pathogens worldwide, could avert 50 million deaths between 2021 and 2030.[58]

Vaccine hesitancy and refusal were abundantly reported during the COVID-19 pandemic,[59-61] as were interruptions to the deployment of new and under-used vaccines.[62] However, the larger, enduring problem for immunization worldwide is a failure of supply and equitable distribution and access to key vaccines, especially to poorer people in low-income countries.[63] Confronting this challenge, GAVI helped to vaccinate more than a billion children between 2000 and 2022 through routine immunization

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programmes.[64] The cost of illness prevented by immunization against 10 pathogens was estimated to be US$ 26 for each dollar invested, averaged across 94 countries between 2011 and 2020.[65] On-the-ground, experimental studies have shown that more people will use COVID-19 vaccines when they are made more accessible, for example by mobile clinics in Sierra Leone.[66]

As mechanisms to provide specific types of foreign aid to low-income countries, GHIs are not uniformly beneficial. A virtue, in the case of vaccination, is that preventive care gets a protected budget. A vice is that large inputs can disrupt rather than strengthen national health services. Sensitive to that criticism, GAVI emphasizes the role of vaccination in developing self-reliant primary healthcare in the countries it supports. Balancing these pros and cons is a work in progress.

National health: prevention as primary healthcare

Preventive care needs extra investment—additional, protected funding—to provide a complementary mix of promotion, prevention, and treatment in primary healthcare.[21] Recognizing this fact in 2002, and motivated by the goals of achieving UHC, health equity and spending efficiency (cutting out costly medical procedures), Thailand ringfenced 20% of the UHC budget for promotion and prevention, funded by general taxation, and provided insurance for the entire population (other than those already covered by social security or civil servant programmes).[21,45,67] Ever since then, Thai government expenditure on prevention and public health (as a percentage of all health expenditure) has been higher than most other middle-income countries.[68]

The governments of wealthy European countries can more easily afford to invest in prevention, if they are motivated to do so (Figure 3.1). One type of motivation is to contain the cost of medical care in their ageing populations. Among societies that are predisposed to redistribution and reciprocity,[12] the 1998 Austrian Health Promotion Fund and Germany's 2015 Preventive Health Care Act give statutory force to prevention, placing obligations on private as well as public healthcare institutions to carry out routine health checks and vaccination programmes, among other responsibilities.[69] Similarly, Finland offers services for promotion and prevention mostly free of charge, and they are widely used. Between 2016 and 2019, the governments of Latvia, Italy, and France expanded programmes of

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prevention and health promotion.[69] In 2022, Spain introduced legal measures to make pregnancy safer, giving women greater choice over termination and surrogate pregnancies, and amending maternity pay. During 2023, France began to offer 'prevention appointments' for citizens at critical ages (20–25, 40–45, and 60–65 years), and to provide non-prescription access to emergency contraception.

There are ways to make prevention work even in countries that are nowadays less disposed to redistribution and reciprocity. The US Prevention and Public Health Fund was established in 2010 with a 10-year budget worth US$15 billion. Although foreshadowed by a long history of preventive care,[70] the Fund was the first type of mandatory investment in public health and prevention in the US.[71] Critics argue that the Fund is too costly alongside large federal budget deficits.[72] Advocates highlight features that appeal to different political constituencies, without diminishing the Fund's effectiveness or distorting the facts. Republican lawmakers, like conservatives everywhere, approve of low public expenditure and small government. They favour opportunities for business over costs to society. They dislike 'socialized medicine' (except for military veterans).[44] They are sensitive to health risks for individuals (e.g. COVID-19 vaccine harms) and resistant to population-wide health interventions (e.g. mandatory use of face masks).[73] They want to know how the Fund would help to contain progressively unaffordable healthcare costs and how it encourages individuals to take responsibility for their own health. Democrats, on the other hand, want to know how the Fund will help widen access to healthcare and reduce inequalities.

These perennial tensions have beset the implementation of the 2010 Affordable Care Act (ACA or 'Obamacare'), created by the Democratic Party in government. ACA has delivered multiple benefits: through compulsory participation, it has markedly increased access to health and preventive care for millions of people, especially Black, Asian, and Hispanic Americans. ACA services with preventive benefits include vaccinations; well-child visits; screening for cancers, HIV, and sexually transmitted infections; HIV pre-exposure prophylaxis; contraception; nutritional assistance; and unemployment subsidies. And these services must be provided without cost-sharing by patients (e.g. without co-payment or co-insurance).[74,75] The ACA also prohibited discrimination based on pre-existing conditions and banned lifetime coverage limits. And yet, the ACA is continually under assault from its detractors, facing calls for repeal from Republican critics of government overreach, the unstable participation of insurance providers,

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difficulties of cost containment, and legal challenges to cost-free preventive care.[70,76]

Community health: all in it together

From E.F. Schumacher's 'Small is Beautiful' (1973)[77] to Hilary Cottam's 'Radical Help' (2018),[78] a wealth of studies show how mutualism, inclusiveness, and solidarity in close-knit communities can support health and wellbeing, often compensating for failures of national health services.[79] The motives for promoting health locally are easy to see: the benefits of investing in valued relationships with family, friends, community, and work colleagues; mutual trust that investing effort, time, and money, often through voluntary work, will produce positive outcomes for people we care about; all underpinned by a long-term (low discount) vision for the future. This is Schumacher's 'economics as if people mattered';[77] it blends with Cottam's view that public services should work *with* people, not do things *to* them.[32,78]

When there is a common purpose—to protect community health rather than maximize corporate profit—willpower can overcome the technical challenges of access, coordination, equity, finance, stewardship, sustainability, training, and trust, among others. Achieving that common purpose is possibly the biggest political challenge for public health worldwide.

In the US, Seattle's Sea Mar Community Health Centers were founded in 1978 to provide comprehensive primary healthcare for the Latino community.[80] Sea Mar has since expanded to become one of Washington State's largest providers of community-based health services. In the north-west of England, Wigan's citizen-led approach to health and welfare is built on the strengths and assets of individuals and communities.[81] Over a six-year period, the 'Wigan Deal' improved healthy life span and the quality of social care. The Deal is seen, not as a tool to be adopted, but as a culture to be grown. And it has support across the political spectrum: Labour councillors see the benefits of strengthening public services and improving the life chances of people living in marginalized communities. Conservatives see value in giving greater responsibility to communities and avoiding excessive reliance on the state.

The Wigan Deal lays down a challenge to the highly pressurized National Health Service—is the NHS willing and able to adopt a culture that gives the public and patients more control and allows staff working in primary

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and community care greater freedom to innovate? The is subsidiarity applied to healthcare—the idea that decisions should be taken at the lowest possible level, closest to where they will have their effects, and where those who take action are responsible for the outcome. This form of 'managed autonomy' combines, for example, the conditions for tax-funded insurance (national) with the need for community participation (local). In this view, the Wigan Deal is not a local refuge from a failing NHS but a model for national healthcare in future.

Health services embedded in communities, workplaces, and schools embrace the idea that health is the shared responsibility of practitioners, patients, and the public. Besides the examples of Seattle and Wigan—very different settings with similar achievements—there is a growing catalogue of successful ways to make health promotion and disease prevention integral to primary healthcare—in healthcare co-operatives, multi-disciplinary or inter-professional practices, and in community and family health centres, operating with powers and responsibilities devolved from national governments.[82]

The last three sections of this chapter have argued that there are incentives and mechanisms to provide preventive care within health services globally, nationally, and locally. These mechanisms can be made easier by efficiency, technology, measurement, and partnership, as follows.

Efficiency: more health for the money

Efficiency might start by making better use of the policies and funding that are already in place.[83] A list made for the US includes: enforce laws already in effect; clarify and update the application of long-standing policies; leverage public and private purchasing and investment power; aid access to programmes by everyone who is eligible for them; and evaluate the effectiveness of population health programmes, agencies, and policies. In addition, make use of existing compendia of do's and don'ts in preventive care.[84]

One way to improve value for money is by identifying sub-groups of individuals who are known to be at relatively high risk of ill-health. Monitoring during pregnancy is an example: although health checks in pregnancy are not generally needed, they are recommended for women who suffer from

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hypertension. High blood pressure during pregnancy carries risks for the mother and for the developing foetus. Focusing on women at risk is more efficient, and the efficiency can be increased in some settings by allowing women to monitor their own blood pressure at home. This reduces the frequency of hospital visits and saves money without, in this instance, compromising on health.[85]

Screening for early signs of cancer among people at relatively high risk, including breast, cervical, and colorectal cancers, is cost-effective against standard benchmarks.[86] The downside of targeting is that it is more specific (fewer false positives) but less sensitive (missing true positives). In other words, a cost-effective strategy compromises on effectiveness to reduce costs. The best strategy in any setting must therefore be judged on cost (affordability) and effectiveness (impact), as well as the ratio of effectiveness to cost. To this end, all initiatives to improve efficiency require data, preferably information that links patients with financing mechanisms in healthcare systems.

The question of whether screening for ill-health should be more or less targeted is one kind of choice in preventive care. More commonly, however, the decision is whether or not to add prevention to essential medical services. Having achieved UHC in the 1980s, the Republic of Korea boosted preventive care in 2003, motivated by the mounting costs of medical treatment in an ageing population, the rise in cancer incidence, the knowledge that cancer mortality can be reduced by early detection, a national health insurance system that covers prevention, advances in screening technologies, plus increased health awareness among the public.[87] Increased funding for early cancer detection has pushed up the overall budget for prevention and public health (Figure 3.4); the reward is measured in fewer deaths from breast, cervical, and other cancers.[88]

Policies for prevention need thoughtful design, based on local knowledge, if they are to serve their intended purpose. For instance, the uptake of preventive care offered by health services, such as HCM and cancer screening, tends to be greater among wealthier and well-educated people who need these services less, an instance of the 'inverse care law'.[89] For prevention, as for other aspects of healthcare that are integral to UHC, policies based on 'progressive universalism' are the way to make sure that people who are poor or vulnerable gain at least as much as those who are wealthy or privileged.[90]

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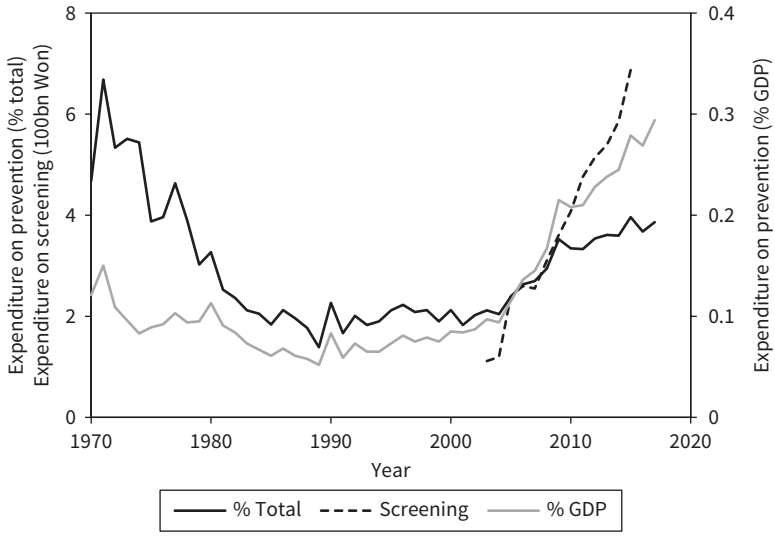

Figure 3.4 Protecting and enhancing the budget for prevention within health services, Republic of Korea. Expenditure on prevention, as a percentage of all health spending (black line), declined between 1970 and 2003, conforming with the pattern in Figure 3.1. Since 2003, the Republic of Korea has increased spending on early cancer detection (secondary prevention, dashed line), roughly doubling the share of total health spending on prevention from 2% to 4% (black line) and pushing up total expenditure on prevention as a percentage of GDP (grey line).

Source: data from OECD Health Working Papers, 101, Gmeinder M, Morgan D, Mueller M, How much do OECD countries spend on prevention?, Copyright (2017), OECD Publishing.

Technology: innovation for prevention

In general, less research money is spent on prevention than on treatment. In cancer care, for example, there have been relatively few economic evaluations of primary prevention (averting disease) compared with secondary and tertiary prevention (earlier or later disease detection and treatment).[86,91,92] A wide-ranging review of US research, covering more than 11,000 projects between 2012 and 2017, found that only a quarter (26%) investigated preventive methods for leading causes of death—including cancer, heart disease, and stroke—even though these conditions are associated with nearly three-quarters of all deaths in the country.[93] The reason

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is partly commercial: for example, far more money is invested in drug discovery than in vaccine development because there is a bigger market for repeatedly purchased drugs than for single-use vaccines. The case for prevention rests on understanding the incentives for investment by private donors, governments, health agencies, and pharmaceutical companies (Chapter 4).

Even so, WHO has ranked preventive technologies among the top innovations for public health, including genomics for early diagnosis and pre-diagnosis of diseases, low-cost diagnostics for HIV and hepatitis B virus, and rapid, remote diagnostics through cell phones, watches, and other devices.[94] To pick just one of these, the accelerating capabilities and plummeting costs of biometric monitoring technologies, enhanced by artificial intelligence (AI), have huge potential to transform the way people look after their health independently and in collaboration with health services.[95] The global wearable medical device market size was valued at US$ 21 billion in 2021, and is forecast to grow more than 10-fold by 2030.[96]

Created from a convergence of wearable fitness devices and clinical monitoring technologies, smart watches, skin patches, headbands, finger clips, and rings now carry an array of sensors to track heart rate, blood oxygen, lipids and glucose levels, food and fluid consumption, and movement and sleep disorders. They can help monitor diabetes and hypertension, identify cardiac dysfunction and neurodegenerative disease, and spot symptoms of infection, such as influenza, rhinovirus, respiratory syncytial virus, and COVID-19.[97-99] Wearables raise personal health awareness, for example by tracking the effects of alcohol on sleep, body temperature, and heart rate. Combining data from multiple devices can build a picture of population health as well as personal health.

Biometric monitoring is generating colossal amounts of data, and novel gadgets have strong commercial, medical, and consumer appeal. Provided the data are accurate, secure, and come in usable form, they will increasingly be trusted by doctors, patients, and the public at large. Where governments are looking for private partnerships in prevention, on the grounds that unhealthy behaviours (physical inactivity, poor diet, alcohol, and tobacco use) are thought to be a matter of individual choice (above), political support could stimulate private investment in the development of diagnostic and monitoring devices. Insurance companies recognize their potential too: digital devices for monitoring physical activity are an aid to reducing health and life insurance premiums.[100]

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Measurement: making health count

Measurement is for management. Health metrics should quantify the value of better health, both for individual and populations, 'not merely the absence of disease'.[101-102] And yet most health indicators in regular use are oriented to the assessment of disease rather than health and wellbeing (Box 2.1).

The right metrics can be used to set benchmarks, track progress towards agreed targets, and embedded in routine practice. For population health, the concept of 'healthy life expectancy', conceived in the 1960s, has eventually become a standard companion to life expectancy (though is still not precisely measured).[103,104] It is useful in revealing, for example, that while life expectancy (from birth) in the UK increased during the years of austerity (2010–18), healthy life expectancy remained about the same, so the proportion of years in good health declined. However, averages conceal large differences between the poorest and wealthiest in society: over the period 2018–20, the most deprived could expect to live 52 years in good health and 26 years in poor health; the least deprived could expect to live 71 years in good health and only 16 years in poor health. A key question for the UK is how to boost healthy life for the poorest, up to the level of the wealthiest. Primary (reducing disease risks) and secondary prevention (identifying and treating early disease) are a big part of the answer.[105]

For health in whole economies, there is mounting pressure to replace GDP with a measure of social and economic welfare, including health, that better serves the broader goals of sustainable development in the twenty-first century (Chapter 1).[106,107]

GDP measures monetary transactions at their market prices, whether or not those transactions are good or bad for health and wellbeing. Commodities that have value but no market price are excluded. Among the exclusions are some of the key ingredients of social (equality, welfare, wellbeing) and natural capital (clean air and water, nutritious food, biodiversity, public spaces) that underpin good health. Resistance to the idea of modifying GDP rests, in part, on the fact that GDP was devised to measure economic activity, not welfare or wellbeing. GDP devotees suggest that other indices should be used to quantify welfare or wellbeing. The alternatives include the Genuine Progress Indicator, the Multidimensional Poverty Index, Human Development Index,[108] the Gross National Happiness Index,[109]

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the Social Progress Index,[110] the OECD wellbeing framework,[111] and the Inclusive Wealth Index.[112,113]

Some of these indices are gaining traction, albeit slowly. Seven wellbeing goals emphasizing health, prevention (of all adverse events), and sustainability are instrumental to the Welsh government's Well Being of Future Generations (Wales) Act 2015.[114] Success in passing the Act depended on key 'policy entrepreneurs' who saw how to solve a pressing problem (climate change), using locally adapted policy (Sustainable Development Goals), in the face of political necessity (the UK government's decision to close the Sustainable Development Commission in 2010).[115] Similarly, New Zealand's 2019 'Wellbeing Budget', introduced by the country's Labour-led coalition government, sought 'to value and to measure all that makes life worthwhile in New Zealand'. All new spending had to support five wellbeing goals: fostering mental health, reducing child poverty, supporting indigenous peoples, creating a sustainable low-carbon economy, and thriving in the digital age (Chapter 1).[116]

The UK Office of National Statistics publishes measures of personal wellbeing that look beyond GDP to health, personal relationships, education and skills, and the environment. In that context, the UK government has begun to explore improved measures of population health—establishing in 2015 a composite Health Index for England.[117] The point of the index is to frame health as a national asset, contributing both to the economy and to the happiness of the population. The index would support prevention by including measures, not just of health outcomes, but also of modifiable risk factors and the social determinants of health. The overall Health Index score for England declined between 2019 and 2020, with the onset of COVID-19. Future analyses will show how this index fares in the aftermath of COVID-19; it may further expose the adverse effects of a decade of cuts in public services (above).

Processes based on global consensus, like those embodied by the SDGs, have the potential to overcome measurement inertia. SDG 3, the principal health goal, has aided prevention by creating indicators and setting targets that require actions within and beyond national health services—for example, to reduce the incidence of hepatitis B and malaria, and to cut deaths from road traffic injuries and from air, water, and soil pollution.[118] However, progress towards the SDGs is slow (2015–23); and some critics would rather focus on specific, measurable, and achievable goals, such as reducing child malnutrition and boosting immunization coverage (Chapter 1).[119]

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Partnership: prevention in all policies

Health promotion and disease prevention commonly require collaboration all along the causal chain, and therefore across government departments. The safety of water and sanitation is monitored by health departments, but construction and maintenance are the responsibility of the environment. Human vaccination against rabies is most effective when reservoir dogs are also vaccinated by veterinary services—taking a One Health approach to preventing rabies infections and epidemics.[120] England's cross-government 'Sure Start' programme for child development, launched in 1999, first increased access to hospital care and then reduced the need for it by limiting infectious diseases, injuries, and mental illness.[121] It improved young children's educational achievements too, with benefits lasting until teenage years. The consequences of alcohol and tobacco use are borne by health services, but policies on taxation and regulation are the remit of central government (Box 2.2).

These collaborations across sectors put 'Health in All Policies' (HiAP)—valuing health in decision-making across the whole of government.[122] Initiatives in other sectors of government that promote and benefit from good health are mostly preventive. In other words, HiAP is, by and large, 'Prevention in All Policies'—a way of binding health to society, economy, and environment in line with the SDGs.

HiAP has been adopted by high-income countries including Australia, Canada, Finland (after the North Karelia project, above), France, and Norway. Among low- and middle-income countries Iran, Thailand, and Vietnam have led the way in placing health systematically in all government policies.[123] In these countries, the benefits are visible in health data collected across multiple sectors with presidential oversight (Iran); in the broader compass of health impact assessments, including biomass power plant projects, patents on medicines, coal mining, and industrial estate development (Thailand); in reducing road traffic deaths through helmet laws, and to contain COVID-19 (Vietnam).[124-126]

Prevention and public health stand to benefit greatly when they are given broad ministerial support.[127] But the reasons why countries from Australia to Vietnam have chosen to do this where others have not, and whether those reasons are transferrable to other countries, are only partially understood. On-the-ground investigation is the way forward.

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Summary

Prevention is an affordable part of primary healthcare in the sense that it is cheap compared with the mounting costs of medical treatment, and good value for money. The motives for investing in prevention differ at global (e.g. international vaccination initiatives), national (aspirations to Universal Health Coverage, UHC) and local levels (commitments to community health). But at all levels, there are ways to make prevention more attractive through efficiencies (low-cost preventive care targeted to people at high risk), technologies (novel vaccines and health monitoroing devices), metrics (for health and wellbeing, not only death and disease) and partnerships ('Prevention in All Policies'). There are, however, other obstacles to navigate. One is that funding is not transferable away from urgent medical care, so prevention needs additional, protected investment, which at first supplements but eventually supplants the treatment of illness.

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4
Epidemics

Unlikely disasters

> It's impossible that the improbable will never happen
> **Emil Gumbel (*Statistics of Extremes*, 1958)**

Predictions of the apocalypse are rarely effective as a call to arms. If the threat of disaster—an earthquake, a pandemic, a nuclear accident—is unlikely or uncertain in time, place, and scale then prevention may not, contrary to expert opinion, be judged better than cure.[1]

Looking to the future, events that are improbable, uncertain, remote, or beyond prior experience are usually given low priority. Doubt dilutes deterrence, even in the face of a fearful hazard. Reflecting on disasters past, the consequences of inaction are frequently a source of painful regret. In 2007, United States Secretary of Health and Human Services Michael Leavitt remarked that 'Everything we do before a pandemic will seem alarmist. Everything we do after a pandemic will seem inadequate'. Leavitt's comment speaks to fundamental principles that more recent COVID-19, Ebola, influenza, mpox, and Zika epidemics did not change (Chapter 2). The challenge, however, is not to change the principles; rather, it is to exploit them more effectively, resolving the prevention-reaction dilemma in favour of the former.

When the sound of alarm bells falls on deaf ears, the rhetorical response is commonly to shout more loudly,[2] and make pronouncements on what heads of government, financial institutions and the United Nations 'must' do.[3] Or to issue slogans ('no one is safe until everyone is safe'), that make little sense to the great majority of people who balance risks on a daily basis.

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There is a better, more pragmatic approach: instead of re-issuing the same stark warnings and blunt directives, it is more productive to appeal to reason: to understand why the threat of a pandemic or some other grave danger fails to elicit action—why prevention is, in effect, not thought to be better than cure. And why, in 2023, the world was still in *A Fragile State of Preparedness*.[4]

The appeal to reason comes in three parts. First and most obviously, adopt the best technical practices when investigating outbreaks and emergencies, including the means of data collection, analysis, and reporting.[5,6] Symbolic of the need in this area, the Global Health Security Index failed dramatically on COVID-19, indicating for example that the US and UK were the world's two most secure countries.[7] They reported the largest (1.1. million) and third-largest (229,000) numbers of confirmed deaths. Second, draw extra power by combining knowledge and skills from different disciplines—epidemiology, social sciences, research and development, diplomacy, logistics, and crisis management.[8] Cross-silo collaboration, and the incentives for doing it, are a recurrent theme of this book. And third—the focus of this chapter—understand how choices and decisions are made in the face of unlikely disasters, based not only on the facts about hazards and risks, but also on the perceptions, values, and motives of all those who have a stake.[6]

Hazard: real and perceived danger

The purpose of preventing an epidemic is mainly to avert a hazard (avoiding a loss), though there may be health gains too, for example, in switching animal-based (potential sources of infection) to plant-based diets.

The facts about a given hazard—the duration of illness, the level of pain, and disability caused, the chance of dying, the months or years of life lost—can all be assessed by standard methods, which are widely used (Box 2.1). However, public health action depends not just on facts, but on perceptions of facts. A hazard usually generates more concern, and is more likely to elicit a response, when the illness or injury has a fearful cause (sharks, snakes and spiders), when the medical effects are gruesome (viral fevers that cause bleeding such as Ebola and Marburg Virus Diseases, Crimean-Congo Haemorrhagic Fever), when children are more likely to be affected than adults (pandemic H1N1 influenza), and when the hazard is new, changing, uncertain or uncontrollable (when a disease first emerges or spreads,

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such as COVID-19, mpox, and Zika virus; Chapter 2). Compared with familiar endemic infections—like malaria, tuberculosis (Chapter 5) and diarrheal diseases (Chapter 7)—emerging epidemic diseases appear disproportionately threatening when judged against objective measures such as the number of people who become severely ill or die.

The sense of threat is heightened when an epidemic is formally classified as an emergency. A Public Health Emergency of International Concern (PHEIC) is a 'serious, sudden, unusual, or unexpected' cross-border threat to health. The declaration of a PHEIC under the International Health Regulations (IHR), is a stimulus for international coordination, fundraising, and for the development of vaccines, therapeutics, and diagnostics that could be rapidly authorized for emergency use.[9,10] But PHEICs have disadvantages too: emergencies interrupt travel and trade (contrary to advice under IHR) and, by concentrating on a single hazard, often destabilize routine health services.[10,11] The PHEIC on-off switch is a cruder device than graded, tiered, less-disruptive approaches to managing an epidemic.[9]

When an epidemic is framed as a matter of security it will be managed on the same level as counter-terrorism.[12,13] The label 'security' signals numerous potential hazards: for critical infrastructure, economic and social stability, health and safety, law and order, and international relations. Having been defined as a PHEIC, the 2014–16 West African Ebola epidemic was also treated as an international security risk. On that basis, US and UK armed forces were stationed in West Africa, commanding vastly more resources than is typically available for epidemic control: US$ 5.9 billion was disbursed by 77 donors in 2014–15.[14] During the COVID-19 pandemic, governments around the world invested massively in security through social and economic protection. And yet large numbers of people needed still greater financial support to lift them out of the crisis, in wealthier as well as poorer countries.[15]

The end of a PHEIC is usually accompanied by the withdrawal of short-term crisis funding, with insufficient investment in preparedness for the next potential threat. The Ebola PHEIC ended in August 2014, and foreign assistance to combat Ebola subsided as the security threat beyond West Africa diminished. The bulk of 2014–15 donations (79%) was spent on the emergency response. Only 18% of funds (compared with 40% pledged) were targeted at longer-term recovery, including primary health care and preparedness for future outbreaks, and only 3% was reserved for research and development into future means of Ebola prevention and treatment.[14,16]

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COVID-19 stimulated a huge scale-up in 'development assistance for health'.[17] In 2020 and 2021, US$ 1.8 billion was provided for pandemic preparedness in low- and middle-income countries and $37.8 billion was provided to manage the health effects of COVID-19. The difference in priorities for prevention and response was stark: funding for pandemic preparedness was 12% of the target set by a G20 High-Level Independent Panel; funding for the health response was 252% of the target.

Given these facts, plus the sharp decline in post-emergency funding for Ebola, the question now is whether pandemic prevention will command the investment it needs through the 2020s and beyond (see next). That will need work in what is now thought to be a post-pandemic world. The World Economic Forum's *Global Risks Report* for 2022 ranked infectious diseases sixth among global risks over the next 10 years; the 2024 report put infectious diseases in nineteenth place.[18] A consequence of pandemic panic is the ensuing pandemic fatigue. On top of this is the tendency to focus on the next big thing—another fresh and visible crisis.

The security label carries another risk, if accompanied by secrecy at a time when accurate data are needed locally, immediately, and publicly for effective disease control. In this context, specialized biosecurity centres risk duplicating instead of reinforcing national public health infrastructures, including networks of health protection teams and diagnostic laboratories. The most resilient health systems are those that work because they are in routine use and, given surge capacity, are always ready to cope with an emergency.[19] These systems need to be built and tested in peacetime, not as disaster unfolds; stronger public health systems bring immediate (no time discount) as well as future benefits.

Because a bigger threat is likely to stimulate a bigger response, there is a temptation towards hazard inflation. Take the case of antimicrobial or antibiotic resistance (AMR). There is no question that AMR is a threat to the health of people everywhere (Chapter 5).[20] However, an influential report published in 2016 concluded that, if AMR is not addressed, antibiotic-resistant bacteria could claim 10 million lives each year by 2050.[21] This estimate is not justified either by the data or by the analysis used to produce it.[22] Nor is it plausible in view of the long-term decline in deaths from infections (fewer than 9 million in total in 2019). And yet it still continues to be cited in 2023.[23] In 2019, 1.27 million deaths were plausibly attributable to bacterial AMR, a substantial health hazard that needs no exaggeration, and a strong argument for the prevention of infection.[24]

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Threat begets action, but subjective judgements about hazards present yet another dilemma. The mixed content of public debate, across a variety of media, is more and less positive for health: pronouncements by authoritative public bodies such as WHO are offset by messages promoting conspiracy theories, fear, stigma, and misinformation. Misinformation (i.e. incorrect information, whether or not deliberate) plays on dread, such as the debunked claim that childhood vaccination is a cause of autism. In counteracting phenomena like the 'infodemic' of COVID-19 misinformation, the public health challenge is to distinguish what is known to be true, what might be true, and what is not true, and for trusted sources honestly to communicate and explain the differences using the proven methods of health campaigns.[25-28]

Hazards and risks are often indistinguishable in the way threats are perceived. When confronting a disaster, there are more options for managing risks and uncertainties, as follows.

Risk: a problem shared

Almost all hazards can be managed if the cost is commensurate with the avoidable risk, while also allowing for uncertainty (Chapter 2). When all individuals in a population are at risk of a defined hazard, but only a small fraction will be affected by it—with the identity of victims and timing unknown—one general tactic is to pool the risk and share the cost. The financial tools to do this include insurance and reinsurance, catastrophe bonds, emergency funds, and risk-sharing agreements.

All these tools have been tried and tested for epidemic prevention. None are exclusively preventive, and none are entirely successful, but they are valuable instruments. The following sections describe some examples.

All the X in one basket

Figure 4.1 maps emerging infections and notable outbreaks of human infectious diseases in new areas, 2003–22. Within that period (2011–21), WHO tracked 2,377 acute public health events due to infectious diseases. These include familiar threats such as cholera, animal/avian influenza, and yellow fever, plus WHO's top 10 emerging disease threats. In 2023 these were COVID-19, Crimean-Congo Haemorrhagic Fever, Ebola and Marburg

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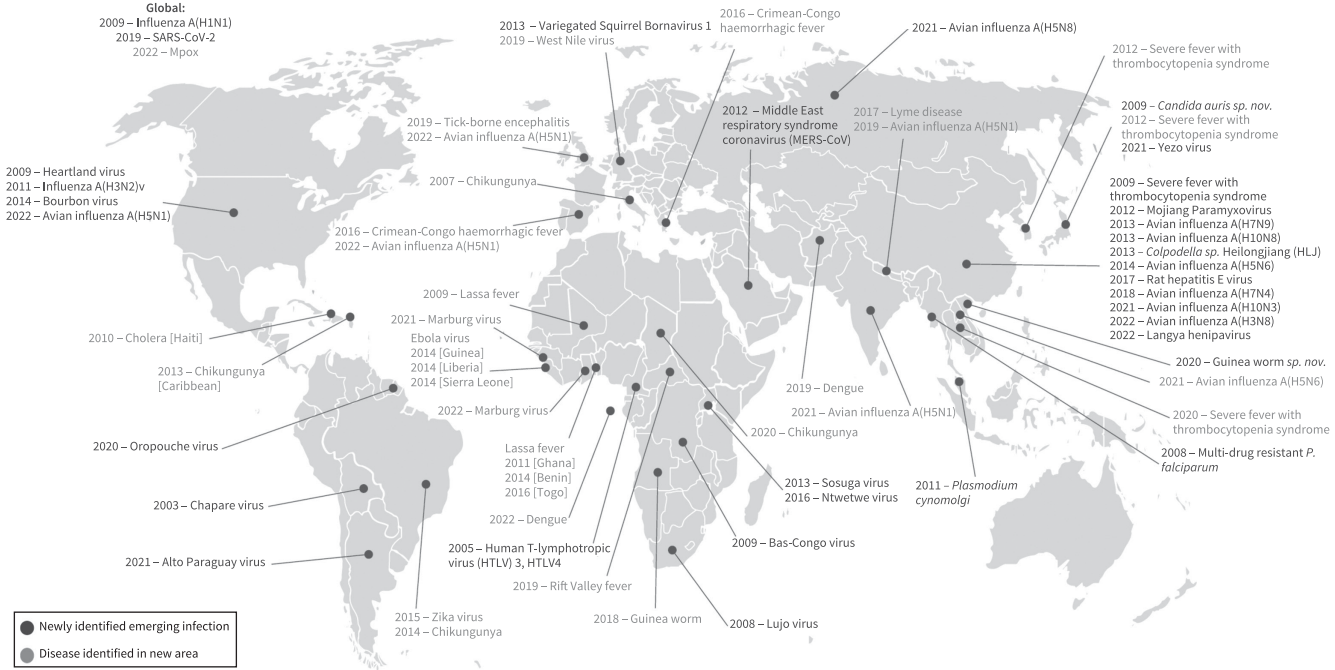
Global:
2009 – Influenza A(H1N1)
2019 – SARS-CoV-2
2022 – Mpox
2009 – Heartland virus
2011 – Influenza A(H3N2)v
2014 – Bourbon virus
2022 – Avian influenza A(H5N1)
2010 – Cholera [Haiti]
2013 – Chikungunya [Caribbean]
2020 – Oropouche virus
2003 – Chapare virus
2021 – Alto Paraguay virus
2015 – Zika virus
2014 – Chikungunya
2019 – Tick-borne encephalitis
2022 – Avian influenza A(H5N1)
2007 – Chikungunya
2016 – Crimean-Congo haemorrhagic fever
2022 – Avian influenza A(H5N1)
2013 – Variegated Squirrel Bornavirus 1
2019 – West Nile virus
2016 – Crimean-Congo haemorrhagic fever
2012 – Middle East respiratory syndrome coronavirus (MERS-CoV)
2009 – Lassa fever
2021 – Marburg virus
Ebola virus
2014 [Guinea]
2014 [Liberia]
2014 [Sierra Leone]
2022 – Marburg virus
Lassa fever
2011 [Ghana]
2014 [Benin]
2016 [Togo]
2022 – Dengue
2005 – Human T-lymphotropic virus (HTLV) 3, HTLV4
2019 – Rift Valley fever
2018 – Guinea worm
2008 – Lujo virus
2009 – Bas-Congo virus
2013 – Sosuga virus
2016 – Ntwetwe virus
2020 – Chikungunya
2021 – Avian influenza A(H5N8)
2017 – Lyme disease
2019 – Avian influenza A(H5N1)
2019 – Dengue
2021 – Avian influenza A(H5N1)
2011 – Plasmodium cynomolgi
2012 – Severe fever with thrombocytopenia syndrome
2009 – Candida auris sp. nov.
2012 – Severe fever with thrombocytopenia syndrome
2021 – Yezo virus
2009 – Severe fever with thrombocytopenia syndrome
2012 – Mojiang Paramyxovirus
2013 – Avian influenza A(H7N9)
2013 – Avian influenza A(H10N8)
2013 – Colpodella sp. Heilongjiang (HLJ)
2014 – Avian influenza A(H5N6)
2017 – Rat hepatitis E virus
2018 – Avian influenza A(H7N4)
2021 – Avian influenza A(H10N3)
2022 – Avian influenza A(H3N8)
2022 – Langya henipavirus
2020 – Guinea worm sp. nov.
2021 – Avian influenza A(H5N6)
2020 – Severe fever with thrombocytopenia syndrome
2008 – Multi-drug resistant P. falciparum
2015 – Zika virus
2014 – Chikungunya
Newly identified emerging infection
Disease identified in new area

Figure 4.1 Newly identified emerging infections and notable outbreaks of human diseases in new areas, 2003–22. The timing and magnitude of each outbreak are uncertain; the total number of outbreaks worldwide every year is large and relatively predictable. A global overview opens the way to managing the combined hazard of multiple, low-risk events with variable impact, for example through surveillance, early detection, and rapid response (secondary prevention).

Reproduced from UK Health Security Agency, Emerging infections: how and why they arise, Copyright (2023). Reproduced under Open Government Licence v3.0. Available at https://www.gov.uk/government/publications/emerging-infections-characteristics-epidemiology-and-global-distribution/emerging-infections-how-and-why-they-arise (accessed 18 July 2023).

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Virus Diseases, Lassa Fever, Middle East Respiratory Syndrome (MERS), and Severe Acute Respiratory Syndrome (SARS), Nipah, and henipaviral diseases, Rift Valley Fever, and Zika.[29,30]

Although the incidence of human infectious disease outbreaks has increased somewhat in recent decades,[31,32] the annual number of events recorded between 2011 and 2021 was predictable within narrow bounds, averaging 216 per year (s.e. 24, range 115–358 per year; Figure 4.2).

Similarly, the WHO African Region reported an average of 86 epidemic and humanitarian events each year between 2001 and 2022 (s.e. 5.1, range 29–129 per year).[33] Thirty per cent of infectious events were zoonotic diseases, dominated by 13 different groups of pathogens. Globally, and in Africa, the total number of events each year is far more certain than the number of events caused by each type of infectious disease or humanitarian disaster.

Also on the WHO list is anonymous 'Disease X' to emphasize that the next emergency could be caused by an unknown pathogen from an

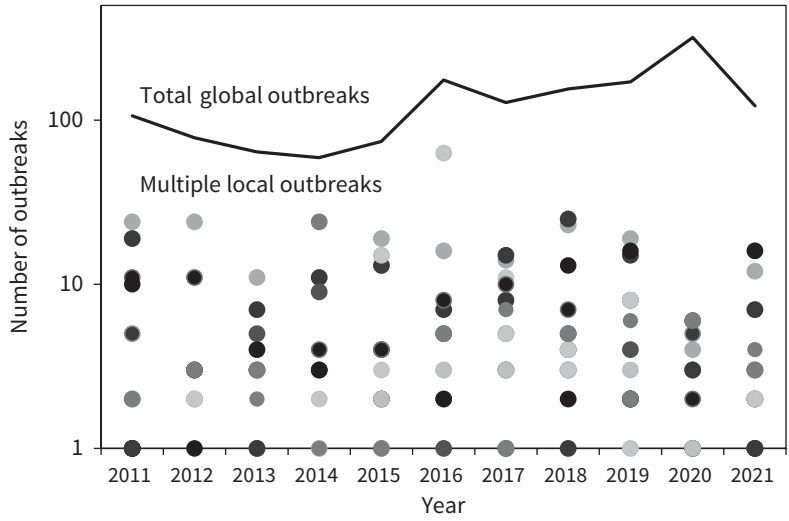

Figure 4.2 Infectious disease outbreaks reported to WHO, 2011–21. The numbers of outbreaks caused by the 10 most commonly reported infections, plus WHO priority infections, were highly variable from year to year (points; average annual coefficient of variation, CV = 0.98), whereas the total was more predictable (black line, CV = 0.57).

Reproduced from WHO Event Management System, courtesy of N. Shindo.

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unknown source with unknown consequences. Disease X could arise through multiple routes: through viral or bacterial mutation; from zoonotic pathogens that jump from animals to humans; or it might even be constructed in a laboratory.

The key point for risk management is that, by developing strategies to contain any and all emergencies, we can turn an unpredictable risk into a predictable one. Certainty is an adjuvant for investment. This logic favours the construction of surveillance systems that are capable of early detection and rapid response to any emerging, contagious hazard. This form of secondary prevention does not preclude primary prevention, but it is often a better interim investment, for reasons explained in the next section.

Primary prevention

Ideally, we would stop epidemics, pandemics, and other disasters from happening at all, through primary prevention targeting these multiple threats (to the left of Figure 4.3).[34,35] But viral emergence from animal reservoirs is still largely unpredictable and unpreventable.[36] Over the decade 2009–19, the US Agency for International Development (USAID) spent US$170 million on evaluating the 'feasibility of pre-emptively mitigating pandemic threats', via the Global Virome Project (GVP).[37] Even though a novel human pathogen is likely to be of animal origin (three-quarters are zoonotic) and most likely to be a virus,[38,39] the chance of identifying the next pathogen by screening the entire global virome is tiny.[40,41] Animal viruses that have the potential to infect people would have to be found among millions of undiscovered virus species.

The search might be more fruitful if focused on more risky pathogens, notably mammalian RNA viruses.[42,43] But the task is still daunting: the primary (wild) host of SARS-CoV-2 is probably a horseshoe bat—the closest coronavirus relative to human SARS-CoV-2, isolated from *Rhinolophus affinis* in Laos, has 96% identity at the whole genome level.[44] But the virus likely entered the human population via an intermediate host.[45,46] It is known what animal species were present at the Wuhan live animal market (in Hubei Province, China), the likely site of spillover to humans, including raccoon dogs, which are susceptible to SARS-CoV-2 infection and shed potentially transmissible virus.[47] But the identity of the primary and intermediate hosts remains unknown.[48]

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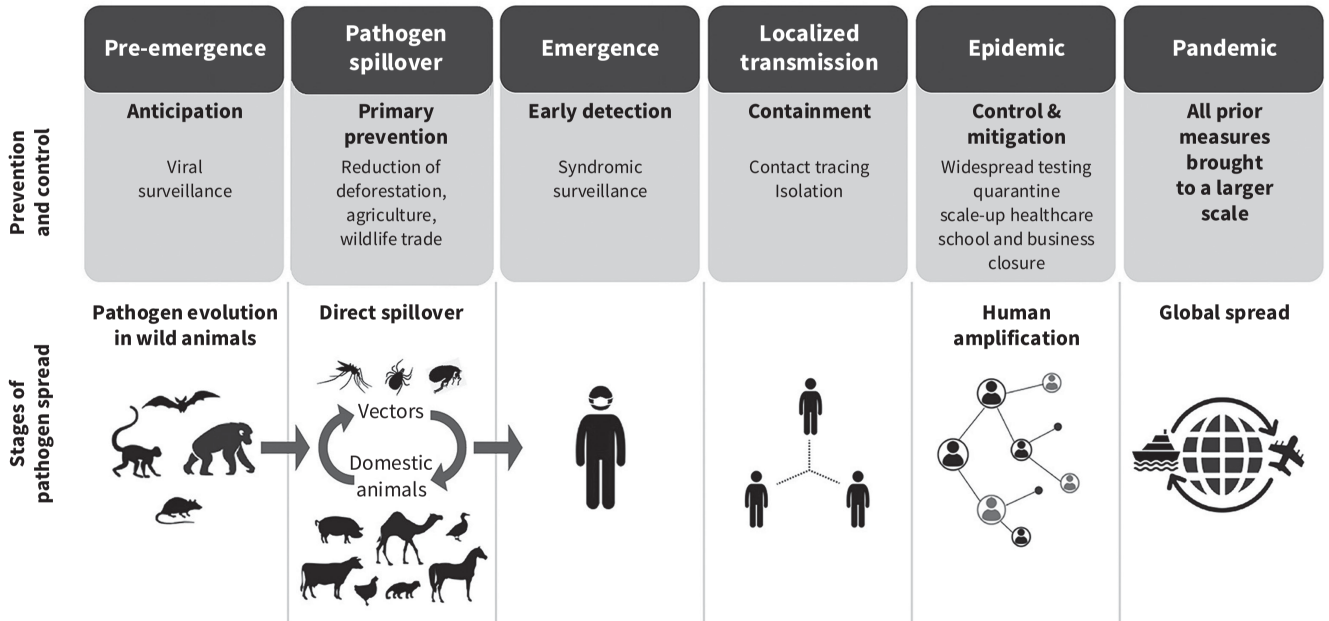

Figure 4.3 Six possible points of intervention to stop epidemics and pandemics, from viral surveillance (primary prevention, left), through early detection (secondary prevention) to local and global outbreak control (tertiary prevention, right). Considering feasibility and impact, early detection is a high priority.

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In general, the genomic signatures of viruses taken from wild animals are only weakly predictive of novel zoonotic diseases,[49] though novel analytical technologies (notably artificial intelligence, AI) are now squeezing more information from data.[50] AI is currently far from predicting Disease X, though deep learning models are getting better at forecasting the emergence of dangerous variants among established human pathogens, such as SARS-CoV-2, Lassa, and Nipah viruses.[51] The great potential of AI comes with cautions: a black swan (an unlikely event) emerging from a black box (of mysterious algorithms) should trigger investigations of validity. But results of proven validity could uncover new epidemiological processes.

To predict a bacterial or viral threat at the cellular level means defining the characteristics of a pathogen that can jump several hurdles: enter different types of human cells, multiply within them, and by-pass innate immunity.[52] At the population level, retrospective analyses can identify broad correlates of epidemic risk, such as land use, proximity of animals, water contamination, and vector abundance. Environmental indicators of this kind have low predictive power in any given setting, though they might help to set priorities for surveillance at the human-animal interface.[31,53,54]

Likewise, influenza A viruses have caused pandemics in birds, mammals, and humans for centuries—probably 14 human pandemics since the sixteenth century. The next pandemic will emerge from among the hundreds of wild and domestic animal species that host influenza viruses, but which, where, and when are unpredictable. Indeed, there may be no discoverable rules of emergence if major outbreaks are caused by extremely rare viral genotypes whose epidemic characteristics can only be understood with hindsight.[55] This would amount to unresolvable uncertainty in the measurement of risk (Chapter 2).

Some detailed ecological studies of disease systems have successfully identified the causes of spillover from wild to domestic animals, such as Hendra virus from Pteropodid bats to horses (case fatality 75%) and people (case fatality >50%) in subtropical Australia. When the bats are unable to find nectar from winter flowering forest trees, they move into urban and agricultural areas, exposing horses and people to virus shed in excreta and spats. Twenty-five years of dedicated fieldwork—monitoring temperature, rainfall, tree flowering phenology, and bat abundance and distribution—yielded a predictive model of spillover.[56] The model is an aid to primary prevention, and similar models could be created from long-term studies of other disease ecosystems, but they are not an efficient way to stop epidemics.

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An alternative solution is to eliminate perpetually risky sources of infection, for example by closing live animal markets (the Wuhan market shut in 2020). Reinforcements include the regulation of trade in wildlife and bush meat, and farm animal biosecurity and infection control.[35] However, the health advantages of such interventions have to be weighed against other costs and benefits: the costs of added biosecurity on farms, and for the enforcement of regulations on animal trade; and the lost livelihoods that follow the closure of markets.

Less targeted environmental interventions, such as halting deforestation, might also help reduce the risk of pathogen spillovers (also primary prevention),[35,57] but health protection is not the main purpose of forest management. This and other examples of primary prevention are typical of health protection outside the health sector (Chapter 3). Health has to be presented as a co-benefit, and made compatible with other key functions of forestry: conserving biodiversity; protecting, air, soil, and water quality; stabilizing climate; sustainable timber production; preserving the livelihoods of Indigenous communities; and tourism and recreation.

Here as elsewhere, there is an extra catch to primary prevention: the return on investment is invisible. To the extent that preventing epidemics is feasible, the main indicator of success is that nothing happens (Chapter 2). Secondary prevention has more obvious rewards, as follows.

Secondary prevention

Because pathogen spillover from animals to people is unpredictable, vigilance is the key. An ideal system will be able to rapidly detect and respond to any kind of emerging health threat around the world—amalgamating the risks from all kinds of hazards (step 3 in Figure 4.3).[57,58]

Surveillance procedures for emerging pathogens have long been available but they are typically under-used. WHO's Technical Guidelines for Integrated Disease Surveillance and Response in the African Region (IDSR) explain how to respond rapidly to any disease outbreak,[59] and the West African Ebola epidemic (2014–16) showed how IDSR can work well if methodically implemented.[16,60,61] Between July and November 2014, twelve Ebola outbreaks in Liberia were investigated in a variant of IDSR, the Rapid Isolation and Treatment of Ebola strategy (RITE). Active case finding and contact tracing were central to RITE, together with methods to protect those caring for the sick and burying the dead. In a comparison of the

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effects of six outbreaks that occurred before the introduction of RITE and six that occurred afterwards, the time between the first new case in remote areas and the notification of health authorities was reduced by nearly half, the proportion of patients isolated increased from 28% to 81%, survival improved from 13% to 50%, the case reproduction number fell below unity (the threshold for disease persistence), outbreaks became shorter (median duration declined from 53 to 25 days), and the number of generations of cases dropped from a median of four to two.

The Republic of Korea took similar steps to detect and contain COVID-19 after the first infected people arrived from China in January 2020.[62,63] After struggling to contain an outbreak of another coronavirus in 2015, agent of Middle East Respiratory Syndrome (MERS), Korea boosted numbers of infection control staff and isolation units, expanded outbreak simulations and training, and strengthened collaboration between medical centres and communities. COVID-19 prompted an aggressive government response aided by public support—people were willing to wear masks, cooperate with contract tracers, and follow authoritative advice. Consequently, fewer than 80,000 cases and only 1,500 deaths were reported within a year of detecting the first case. Korea's success was replicated in other countries: in general, virus testing with isolation, and contact tracing with quarantine (together 'test, trace, and isolate', TTI), help to reduce SARS-CoV-2 transmission.[64]

Post COVID-19, there is a vast array of initiatives to strengthen any surveillance and response to emerging pathogens. Protocols include the 7–1–7 target, in which every suspected and actual outbreak would be detected within 7 days, reported within 1 day, and have all essential control measures in place within the following next 7 days.[65] Among possible control measures is an array of 'non-pharmaceutical interventions' besides TTI, depending on the nature of the pathogen—environmental controls, barriers (e.g. face masks and other personal protective equipment), social distancing and lockdowns, and restrictions on movement.[63] These are the first line of defence against any novel pathogen, deployed before the development of specific vaccines and therapeutics (see 'Technology platforms', later on).

As surveillance systems for SARS-CoV-2 and COVID-19 are scaled down post-pandemic, the task ahead is to integrate new proposals into a globally coherent, financially sustainable architecture for prevention, preparedness, and response, linking all the key elements—event detection; risk assessment; diagnostics and genomics; reporting and data sharing.[66]

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Reinforcing existing systems that are 'always on' is better than creating stand-alone facilities that lie dormant between crises ('break glass in case of emergency'); this applies to public health laboratories, which can be given surge capacity in the event of an unfolding crisis.[67] This approach gives an immediate functional return on investment (plus peace of mind), and a future (time-discounted) return on investment during an unanticipated disaster.

Nobody knows when Disease X will emerge or what it will be, but some looming threats justify immediate and continuous monitoring. Since the 2021 onset of a worldwide 'bird flu' pandemic (which may now be widely endemic), tracking the spread of highly pathogenic avian influenza (HPAI subtype H5N1) viruses from birds, especially poultry, into mammal and human populations is a top priority.[68,69] Around 50 domestic, wild, and farmed mammal species have been found infected with H5N1. The number of species affected is certain to rise, and some of the viruses isolated carry molecular markers associated with viral replication in mammalian cells.[70] H5N1 viruses are highly pathogenic to humans, with a case fatality of 50–60%, and there are persistent and abundant opportunities for human contact with these viruses. The H5N1 pandemic has already been calamitous for domestic and wild bird populations worldwide; the detection of regular transmission among mammals or humans would threaten a global public health emergency.

Pooled finance

If risks are pooled and costs are shared, those who pay expect a reward. The *Commission on a Global Health Risk Framework for the Future* calculated that the loss to society from potential pandemics is more than US$60 billion each year, with a 10% chance that the loss could be more than twice that amount. To counter that loss, they proposed spending an extra US$4.5 billion per year in preparing for pandemics—or 65 cents per person.[13,71] A large part of that sum, US$3.4 billion, would be used to upgrade public health infrastructure and capabilities in low- and middle-income countries—an insurance policy covering a wide range of risks to health. Another US$1 billion would fund research and development for epidemic diseases. The 65 cents per person looks like good value for a small sum of money, but the costs and benefits are incurred by and accrue to different people. Given all the other worthy causes in the world, wealthy donors

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might also ask how they could get a better return on $4.5 billion per year, even if it costs just a few cents per person.

The idea of insuring against health emergencies has been explored in a diversity of schemes. Development Impact Bonds (DIBs) and Social Impact Bonds (SIBs) are three-way contracts in which private investors finance development and social programmes, an agency (often public sector) delivers the programme, and governments (SIBs) or donors (DIBs) eventually pay back investors. The payback is the principal plus a return, which is provided if, and only if, the programme succeeds in achieving its goals.[72,73]

Health interventions of proven effectiveness should be attractive to capital-rich investors. The prevention of African sleeping sickness, transmitted by tsetse flies, is a case in point.[74] *Trypanosoma brucei rhodesiense* is a pathogen of animals, including cattle, that occasionally spills over to humans, for whom it is almost always fatal. The mass treatment of cattle with trypanocidal drugs, followed by the application of insecticides to deter tsetse flies, gives a double benefit, preventing infection in valuable livestock and susceptible people (another example of 'treatment as prevention'; Chapter 5). The successful use of DIBs for sleeping sickness could open the way for other similar applications, such as vaccination to prevent rabies in domestic dogs and people. However, DIBs have not yet been used for the prevention of sleeping sickness, rabies, or any other infectious disease, though they have been used for other health projects and for poverty alleviation more broadly.[75,76]

Some innovative insurance mechanisms have failed practical tests. The World Bank's Pandemic Emerging Finance Facility (PEF) has its origins in 'catastrophe bonds', putative instruments for insuring against disasters such as hurricanes.[77] The intention of PEF was to persuade insurance companies to take on some of the risk posed by catastrophic epidemics of Ebola, coronaviruses, influenza, and other infectious diseases. But PEF hit two major snags.[78,79] One was that the trigger for payouts to affected countries was too slow—the money would be provided only when an outbreak had satisfied a complex set of epidemiological criteria. By design, the PEF insurance scheme would have released funding only twice between the years 2006 and 2019, even though five PHEICs were declared over that period—H1N1 influenza in 2009, polio in 2014, Ebola in 2014 and 2018, and Zika in 2016.[80] A slow response to a rapidly expanding epidemic means that many people could become ill or die before any funding is received. The other hitch was that interest payments were unduly favourable to rich-country investors, leading to the charge that PEF bonds are an overpriced handout

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to speculators.[81] By July 2020, PEF had paid out roughly US$150 million to 48 countries affected by COVID-19. At around the same time, the World Bank announced that it would not issue any future bonds.

The failed PEF was superseded by a new Pandemic Fund in September 2022, also hosted by the World Bank.[82] Abandoning insurance mechanisms, the new fund will disperse pooled funds through a pre-defined list of implementing agencies. The fund will place more emphasis on pandemic prevention and preparedness than PEF, even though rapidly financing the response to unpredictable outbreaks remains a vital need.[80] By January 2024, 24 sovereign and three philanthropic donors had given around US$2 billion to the nascent Fund, well short of the estimated US$10 billion needed each year.

The World Bank has traditionally disbursed far more money through other mechanisms, such as those linking disbursement directly to programme results. In March 2023, there were 146 such operations worth US$47.8 billion, which have also served as a platform to mobilize a further US$500 billion.[83] Many of the projects funded by this mechanism tackle the preventable risks of illness in a different way from the pandemic funds—for example by strengthening health, water, and sanitation systems in low-income countries.

In short, pooled financing mechanisms, as a vehicle for collective action, are a potentially valuable set of tools that have had mixed fortunes. In terms of returns on investment, they illustrate the difficulties of global coordination, and of stimulating motivation. This is true not only for pandemic prevention, but also in mitigating the commercial determinants of ill health (Chapter 6) and climate change (Chapter 8).

Inclusive risk

The argument for preventing a health hazard is more compelling when a large number of people are at risk, not just the marginalized few. In the US in 1981, cases of a rare lung infection, *Pneumocystis carinii pneumonia (PCP),* were found in five young, previously healthy gay men in Los Angeles. This was the first report of HIV/AIDS, which was initially known publicly as a 'gay disease' and medically as gay-related immune deficiency syndrome (GRID).

HIV/AIDS was also known to be a disease of haemophiliacs as early as 1981. But in 1984, Ryan White, a haemophiliac teenager from Indiana,

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was excluded from school after becoming infected through contaminated blood. White's advocacy for AIDS research and awareness helped break the stigma of HIV/AIDS as a gay disease. In January 1983, HIV/AIDS was reported among female partners of infected men showing that the virus was heterosexually transmissible too. Throughout the 1980s it became clear that HIV/AIDS was a threat to everyone, not only in the US but worldwide.

The Ryan White CARE Act (Comprehensive AIDS Resources Emergency Act) passed by Congress in 1990, the year of White's death, has since become the largest federally funded programme in the US for people living with HIV/AIDS. It was also a progenitor of the United States Leadership Against Global HIV/AIDS, Tuberculosis, and Malaria Act of 2003, which in turn led to the President's Emergency Plan for AIDS Relief (PEPFAR). PEPFAR is the largest commitment ever made by any nation for an international health initiative dedicated to a single disease (despite its debatable economic rationale[84]). In its first 20 years of operation, PEPFAR gave more than US$110 billion to support HIV treatment, prevention, and care services; laboratory infrastructure; and to scale-up and train the health workforce.[85] In 2022, 30 million of an estimated 39 million HIV-infected people worldwide had access to life-saving antiretroviral therapy (ART), with a large contribution from PEPFAR especially in sub-Saharan Africa.

Notwithstanding its success, PEPFAR faces an uncertain future.[86] Even though 630,000 people died of AIDS-related illnesses in 2022, the disease is now merely a public health priority rather than a security emergency.[87] Due largely to the success of ART, HIV/AIDS is a diminished hazard both in medical fact and in political perception (Chapter 5). Added to this is the growing opposition among political conservatives to funding reproductive health programmes. These factors will test resolve to use PEPFAR to support the long-term care of patients in health services, superseding its original role in containing an emergency.[85]

Technology platforms

The decision to invest in making new health technologies—devices, diagnostics, drugs, instruments, reagents, vaccines—depends on the chance of developing an effective product and the size of the potential market, among other factors. From the perspective of pharmaceutical companies, the development of vaccines (preventive) is generally less rewarding than drugs (curative), as reflected in the vastly different sizes of their global markets.

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Drugs are a trillion-dollar market annually, whereas vaccines bring revenues of around US$50 billion.[88] The main explanation for the difference is that an effective vaccine is usually given just once (or a small number of times) to each person at risk whereas drugs can be prescribed repeatedly.

Investment in vaccine development should be more appealing when co-funded (pooled risk), when a target product has multiple uses (applicable to whatever Disease X turns out to be), and when it can be rapidly deployed (a readily adaptable product). Considering all these factors, the Coalition for Epidemic Preparedness Innovations (CEPI) was set up in 2017 to accelerate vaccine discovery, development, and deployment—a partnership between public, private, philanthropic, and civil society organizations.[89] Guided by WHO's list of top 10 targets for R&D (above), shared investment aims to develop more vaccines against the coronavirus diseases MERS, SARS, and COVID-19, plus Chikungunya, Ebola, Lassa, Nipah, and Rift Valley Fever.

CEPI's operational model makes use of platform technologies. These rapid response platforms use a generic module based, for example, on a viral vector, or synthetic DNA or RNA, to deliver a gene that encodes an agent which induces protective immunity (Figure 4.4).[90,91] The platform is a plug-and-play template—one process that can be used, with minor alterations, to make different vaccines using a common technology.[92]

The investigation of prototype pathogens invokes the same idea.[93] Choose a model virus in each of the families that have a history of causing epidemics and pandemics—Coronaviridae (SARS-CoV-1, MERS, SARS-CoV-2), Orthomyxoviridae (influenza), and Paramyxoviridae (Nipah, respiratory syncytial virus)—and investigate its diagnostic assays, animal models, antigenic targets, and potential immune correlates of protection.

Platforms and prototypes should enable manufacturers to develop new vaccines for specific pathogens at a sprint, to cut the cost of building manufacturing facilities, and to streamline regulatory processes. Ideally, preclinical, safety, and efficacy trials take place in parallel, not in sequence. Platforms work: conventional (e.g. inactivated and live viruses) and novel templates (DNA and RNA, notably mRNA) have been used to develop high-efficacy COVID-19 vaccines, four of them by CEPI and partners (as of July 2023).[94]

The successful development of COVID-19 vaccines within a year of its emergence has fired ambition: the *100 Days Mission to Respond to Future Pandemic Threats* aims to reduce the impact of future pandemics by making diagnostics, therapeutics, and vaccines available within that period, far quicker than was conceivable before COVID-19.[95] But technologies also

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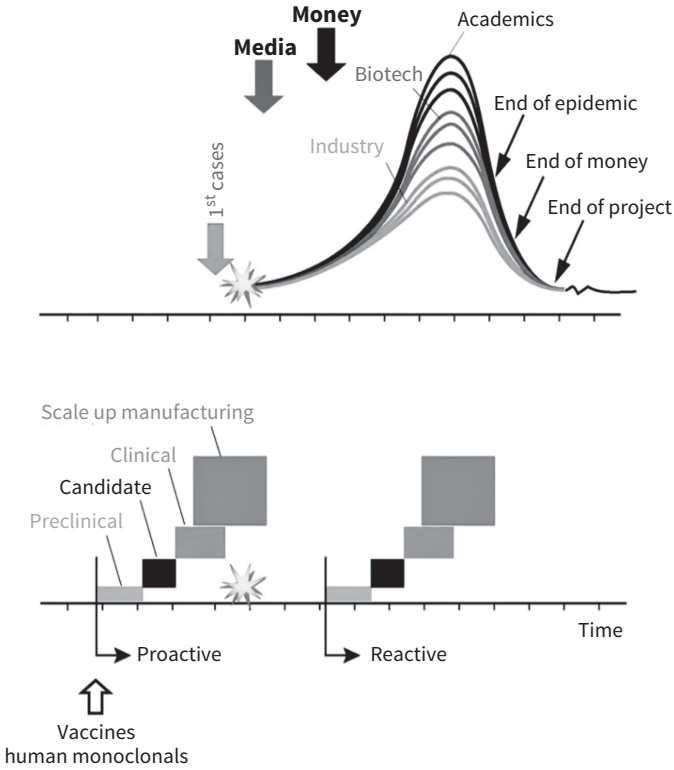

Figure 4.4 Sharing and anticipating risk through technology platforms. Top: the usual reactive steps in vaccine development and delivery, lagging behind the emergence of a single novel pathogen. Bottom: the earlier timing of a proactive approach to create generic platform technologies that are precursors for vaccines and other technologies to prevent infection with a range of different pathogens, some of which are not yet known (Disease X).

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need platforms for distribution. COVAX, led by WHO, GAVI, and CEPI, was an international mechanism for sharing the costs, risks, and benefits of COVID-19 vaccines. COVAX promised fair and equitable access for countries worldwide, especially low- and middle-income countries. Judgements of its performance have ranged from 'naively ambitious' to 'far better than anticipated'.[96,97] COVAX delivered nearly 1.9 billion doses of vaccine to

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people in 146 countries by the end of 2022. This included 73% of all doses supplied to low-income countries, though vaccine coverage in these countries was still only 25% of target.[98] The unequal distribution COVID-19 vaccine clearly cost many lives: by one analysis, sharing vaccines by need rather than wealth could have prevented more than a million deaths worldwide by the end of 2021.[99] Reflections on the successes and failures of COVID-19 vaccination must range along the whole supply chain, from innovation to implementation to impact. The delivery of new technologies, following their development, needs its own *100 Days Mission*.

Health regulations

International conventions, regulations, and treaties aim to prevent the spread of infection by creating frameworks for mutual benefit, stimulating cooperation and coordination, sharing costs, and pooling risks.

Originating in Europe's nineteenth-century defence against cholera, the International Health Regulations (IHR 2005) are the only treaty governed by international law that is designed 'to prevent, protect against, control, and provide a public health response to the international spread of disease'. Unlike their historical antecedents, the IHR 2005 are not limited to specific diseases (originally cholera, plague, yellow fever) but apply to new and ever-changing public health risks, including air pollution and nuclear accidents.[9,100] Under IHR 2005, WHO has the power to declare a PHEIC, and has done so for H1N1 pandemic 'swine flu' in 2009, polio in 2014, Ebola in 2014 and 2018, Zika in 2015, COVID-19 in 2020, and mpox in 2022.

The signatories to IHR 2005, the States Parties, are legally bound to notify all emergencies to WHO that pose an international threat, to permit verification, and to inform other States of the risks they face. The potential benefits are clear: by sharing information, the governments of affected countries can also share the cost of confronting a new hazard, receive technical assistance and logistical support, and gain access to new technologies.[101] No country can single-handedly develop diagnostics, drugs, or vaccines for Ebola, Zika, or COVID-19.

But disclosure carries costs as well as benefits. Governments may fear that external verification jeopardizes security or sovereignty, even if it comes with financial or technical support. They may be concerned that reporting an outbreak will lead to restrictions on the movement of people and goods between countries, with benefits for health but costs to the

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economy. Although the IHR 2005 stipulate that there should be no 'unnecessary interference with international traffic and trade', at least 30 countries did impose such restrictions on travellers from West Africa during the 2014–16 Ebola outbreak.[102] These regulations, restated during the epidemic by WHO, were ignored at the convenience of IHR signatories, and with impunity. One analysis of eight major disease events that occurred between 2013 and 2018 found 210 instances of governments implementing health measures that contravened the IHR 2005. The most frequent breach was to deny entry to international travellers.[103] During the COVID-19 pandemic, almost all countries decided that restrictions on international travel were necessary to prevent the importation of infections. They therefore restricted visas, closed borders, and imposed quarantines, with varying degrees of success. Through tight border controls, Singapore and New Zealand maintained Zero-COVID status into 2021; Hong Kong and Mainland China did so into 2022. Other attempts to stop COVID-19 from crossing borders were less successful: by the time the SARS-CoV-2 Omicron variant was first reported in southern Africa (in November 2021), 6 of the 8 largest lineages were already circulating in England. Even after travel to the UK from southern Africa was restricted (also in November 2021), Omicron continued to enter the UK from well-connected secondary locations.[104]

Most treaties that aim to foster global cooperation do not achieve their intended results; the main exceptions govern international trade and finance.[105] For health, the Framework Convention on Tobacco Control (Chapter 6) and the Paris Agreement on climate change are partially successful, and the Montreal Protocol on Substances that Deplete the Ozone Layer was a landmark multilateral agreement on the environment (Chapter 8).

For IHR 2005, given the trade-offs between health, economy, sovereignty and security, and the difficulties of enforcement, it is no surprise that compliance has been poor, compromising the treaty as a mechanism for sharing costs and risks. A 2015 review found that 78 out of 196 countries failed to report on IHR 2005 at all, and those that did report achieved low scores (between 55% and 87%) on core capacities. There were reporting gaps on antimicrobial resistance, biosafety and biosecurity, preparedness, emergency response operations, medical countermeasures and personnel deployment, and chemical events and radiation emergencies.[106,107] During

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the COVID-19 pandemic, the IHR 2005 led to the declaration of a PHEIC but not a coordinated international response to it.[108]

The Ebola, Zika, COVID-19, and mpox emergencies reignited debate about how to make IHR 2005 more effective. Amendments to the Regulations made at WHO's 2024 World Health Assembly upgraded the definition of a pandemic emergency, aiming to trigger more effective and collaborative international responses to events that could turn into pandemics. The amendments also emphasized equitable access to medical products and financing; streamlined the function of emergency committees; stressed the value of timely and transparent information sharing; and made it clear that restrictions on travel and trade during health emergencies should be evidence-based, proportionate, and non-discriminatory.[109,110]

The renewed IHR 2005 has to be implemented in view of one enduring truth: national governments act primarily in the interests of their own citizens. An unenforceable body of international law, whether it be IHR 2005 or a new pandemic treaty that operates in parallel with the Regulations,[111] will only function on the basis of reciprocity, not coercion.

On the matter of resolving disputes that prevent collaboration, some lessons can be drawn from efforts to share intellectual and material property, as follows.

Intellectual and material property

Within the broad framework of IHR 2005 lies the question of how to share information and materials, to the benefit of individual owners of the data and the whole research community. These assets are often seen as public goods that should be made freely available, especially in an emergency. But intellectual and material property have commercial, political, and professional value. The governments of affected countries are concerned that biological data and materials will be used to produce treatments they cannot afford; scientists sharing data worry about losing credit for a discovery; and biotechnology companies want a stake in developing or manufacturing new diagnostics, drugs, and vaccines. Intellectual property is a sticking point in negotiations over WHO's proposed pandemic treaty: biotech companies insist that IP is vital for investment in R&D; proponents of health equity

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argue that IP restricts access to new technologies during emergencies, as demonstrated by COVID-19 vaccines.

In 2006, following a dispute over commercial vaccine development by a foreign company, Indonesia agreed to share samples of influenza A virus (H5N1, 'bird flu') on the condition that WHO and other countries guarantee access to vaccines derived from samples it provided.[112] This specific issue, framed as a matter of property and sovereignty in international law, eventually led to a general solution—the Pandemic Influenza Preparedness (PIP) Framework (2011)—with which Indonesia complied (they resumed sample sharing in November of that year).

Co-operation also needs to be well-organized. PIP is an international instrument for sharing H5N1 and other influenza viruses with human pandemic potential, and for providing access to vaccines. Several databases operate alongside PIP. One of these, the Global Initiative on Sharing Avian Influenza Data (GISAID), has become a primary source of genomic data, now including information on all influenza viruses and COVID-19.[113,114] Two other important repositories of genome data are virological.org (University of Edinburgh) and Genbank (US National Institutes of Health). As of 2023, these three repositories are not connected to each other or to local data systems, and they operate under different rules for data sharing, commercial use, and intellectual property.[115] And yet global surveillance needs cohesion, providing mutual access to genomic data bases, the integration of genomic and other types of surveillance data, and practical ways to share the benefits.[116]

From the perspective of public health, the principles are clear and widely-agreed, even if practical obstacles stand in the way: data should be findable, accessible, interoperable, and reusable (FAIR) for all parties.[111] Furthermore, fairness should embrace equity, not merely equality, where participants are expressly provided with the information they need to succeed. The sharing of benefits is vital to the success of PIP, IHR, and any new pandemic treaty that might be agreed upon in 2024.

Summary

If the threat of disaster—an earthquake, a pandemic, or a nuclear accident—is unlikely or uncertain in time, place, and scale then prevention

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and preparedness may not be better than treatment and cure. Tactics that favour the prevention of an unlikely disaster are routinely used by the insurance industry: spotlight preventable hazards, pool the risks, and share the costs. A hazard—such as COVID-19, Ebola, or Zika virus—is perceived to be more dangerous, and more likely to stimulate action, when classified as a public health emergency or a threat to national security, and when the severity of a hazard changes suddenly and unpredictably in space or time. The methods for pooling risks and sharing costs include: early detection and response systems for multiple pathogens, including an unknown, unpredictable Disease X; mechanisms for sharing genomic and other surveillance data; platform technologies for the development of new diagnostics and vaccines; and collaborations through the international conventions and regulations. Although primary prevention is preferable, secondary prevention is often a better interim investment: preventing the emergence of Disease X is not generally feasible; stopping its spread by surveillance, diagnosis, isolation, quarantine, and vaccination is practical and essential.

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5
Endemic infections

Normal ways to die

> Tuberculosis is killing someone every 20 seconds
>
> **The TB Alliance (2023)[1]**

A tuberculosis (TB) death every 20 seconds adds up to 1.6 million lives lost each year. That makes *Mycobacterium tuberculosis* the biggest cause of death from a single infectious agent worldwide. And yet TB, like other everyday diseases, is rarely seen as a health emergency. Tackling the pandemic of TB and other neglected, endemic diseases begins, not by insisting that millions of deaths constitute a crisis, but by understanding why they are acceptably normal.

Historically infamous as the 'captain of all these men of death', TB is no longer considered to be the disease threat that its persistent death toll might suggest, and the fight against TB has struggled accordingly (like HIV/AIDS, Chapter 4). Complacency is one challenge, competition for resources is another. A hazard is judged comparatively and the value of TB control may have fallen further against other current priorities—cost of living, climate change, food insecurity, migration, and conflict.

With respect to prevention, the present conundrum of TB control is that primary prevention is feasible on a large scale but not effective (BCG vaccination) and secondary prevention is effective but not feasible (treatment of latent infection). Curative treatment is effective and also the main form of prevention (interrupting transmission).

For three decades, early diagnosis and treatment of disease has been the central pillar of TB control. This is the focus of the WHO-IUATLD DOTS (directly observed treatment, short-course) strategy launched in the early

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1990s, and all its subsequent derivatives.[2] While a new, high-efficacy vaccine is much needed, TB treatment with combinations of drugs is still the most effective way to reduce the burden of illness and death. For TB, the prevention-cure dilemma can be resolved by treatment as prevention: chemotherapy cures the disease, saves lives, and also prevents the transmission of infection.

Nonetheless, the implementation of DOTS and its refinements has been slow. After decades of missed targets for TB control, the unfulfilled potential of treatment remains immense. Through a history of notoriety TB has claimed, and has been given, special status, set apart from other health programmes. This has been a mixed blessing, arguably with more costs than benefits today. At the UN General Assembly in September 2023, the high-level meeting on TB was disconnected from parallel meetings on Universal Health Coverage (Chapter 3) and pandemic prevention (Chapter 4).

TB separatism is still pervasive, reflected for example in the top-down (vertical) approach to introducing technological innovations.[3] One way to make faster progress is through integration—in particular, by combining the strengths of TB control programmes, primary healthcare and social protection, as mutually reinforcing ways to achieve UHC. Another is to reset perceptions of TB as a hazard—the threat level rises when a normally endemic disease becomes epidemic driven, for example, by HIV infection and exacerbated by the emergence of strains resistant to first- and second-line drugs.

Familiarity breeds neglect

TB claimed the lives of a pantheon of celebrities in the nineteenth and twentieth centuries—John Keats (1821), DH Lawrence (1930), Simone Weil (1943), and Vivien Leigh (1967) among them—drawing attention to the huge social burden of the disease. That burden, largely anonymous, amounted to 100 million lives lost in the twentieth century alone.[4]

Despite the development of efficacious drugs since the 1940s, TB still imposes a major burden on health and health services around the world. There were an estimated 10.6 million new cases in 2022, leading to 1.3 million deaths, a high case fatality ratio (about 12%) for a largely curable disease (COVID-19 case fatality is <1%).[2]

Reaching UHC depends on matching health service supply with public demand (Chapter 3), and yet these are likely to be different in the case of

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Table 5.1 Estimated numbers of deaths from Ebola and tuberculosis, with expenditures and economic costs taken over a 12-month period in 2014 and 2015

	Ebola (W Africa 2014–15)	**Tuberculosis (Global 2014)**
Expenditure (US$ bn)	5.9	6.8
Economic cost (US$ bn)	53	41
Deaths	11,310 –	9,700 (W Africa) 1.33 million (Global)

Note: Ebola deaths are as reported during the whole of the West African epidemic, mostly in Guinea, Liberia, and Sierra Leone.[86] Ebola funding is the total disbursed by donors, September 2014 to October 2015.[86] The estimated economic cost of the Ebola epidemic was made by Huber et al.[87] TB deaths exclude those among HIV-infected people, as estimated by WHO.[2] TB funding is for drug-sensitive cases in the low- and middle-income countries that reported 97% of all cases globally in 2018. TB economic costs are the annual average for the period 2000–15.[88]

Source: data from N Engl J Med, 375(6), WHO Ebola Response Team, After Ebola in West Africa: unpredictable risks, preventable epidemics, pp. 587–96, Copyright (2016), Massachusetts Medical Society; J Infect Dis., 218(suppl_5): Huber C, Finelli L, Stevens W, The economic and social burden of the 2014 Ebola outbreak in West Africa, pp. S698-S704, Copyright (2018), Oxford University Press; World Health Organization, Global tuberculosis report 2023, Copyright (2023); Global TB Caucus, The price of a pandemic 2017, Copyright (2017).

TB. From the perspective of health services, TB is a major health problem—ranked thirteenth among all causes of death, and first among single agents of infection. Members of the public may see it differently: placing TB among all of life's risks and hazards, only about 2 in 10,000 people die from TB each year.[5]

Because the numbers of new cases and deaths change little from year to year,[2] TB also has a problem of perception: as for other endemic diseases, and unlike epidemic diseases, normal is not notable. The hazard is diminished by habituation. A comparison with Ebola makes the point (Chapter 4). Ebola is a dreaded disease; TB much less so. Despite these differences in perception, TB and Ebola both have a case fatality ratio of around 50% if untreated, falling to 15% with medical care. And yet, during the West African Ebola emergency of 2014–16, the costs of managing the epidemic in Guinea, Liberia, and Sierra Leone, and the full economic costs of the epidemic, were about the same as for TB worldwide (Table 5.1). The estimated number of TB deaths in the three West African countries was of

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roughly the same magnitude as those for Ebola (both around 10,000), but the global death toll from TB was more than 100 times greater.

As a hazard to individuals, TB is intrinsically less fearful than some other threats to health and life. Advocates of TB control are fond of counting the number of lives lost from TB in units of crashed jumbo jets. But that statistic misses a key point: a plane crash incites a far greater level of fear than TB, in part because airline passengers have no control over their fate. There is little tolerable margin for error on aircraft safety. News of every accident is broadcast worldwide. The huge investment in crash prevention, to meet internationally agreed safety standards, makes commercial flying almost risk-free (there was approximately 1 fatality for every 6 million flights in 2022). In contrast, TB is a life-threatening but indolent and curable disease, and mainly a disease of adults (less emotively than children; Chapter 2). If contracting TB is improbable, and can anyway be cured, why go to the trouble of preventing it?

The International Health Regulations (IHR 2005) could, in principle, be used to help contain the worldwide spread of TB.[6] But unlike COVID-19, it is doubtful that TB will ever be classified as a Public Health Emergency of International Concern (PHEIC) under IHR 2005 because endemic TB is not usually considered to be 'serious, sudden, unusual or unexpected', or the cause of 'an extraordinary event' (Chapter 4).

TB is present in most months of the year in most countries in the world; if the million or more TB deaths that occur annually were to happen in a single month at an unpredictable location, the response would be far greater, and not simply because health services would be overwhelmed.

Forgotten, but not gone

The chronic invisibility of endemic, unchanging illness and death—caused by TB among many other conditions—is an enduring challenge to public health (Chapters 2 and 6). One of the most successful responses in the past decade has been the joint branding of a group of about twenty (classifications differ and change) transmissible pathogens as 'neglected tropical diseases' (NTDs), including dengue, leishmaniasis, onchocerciasis (river blindness), schistosomiasis (bilharzia), and intestinal helminths (roundworm, hookworm, whipworm, and others).[7] Amalgamating the risks, NTDs are presented as one big cause of disease that is less easily overlooked, rather than many small diseases each of which can be ignored (Chapter 4). For more effective control, the NTDs have been integrated with each other, and with water, sanitation, and hygiene services; immunization programmes; insect

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vector and malaria control; and primary healthcare.[8] TB is not formally a NTD and is not quite so neglected, having been recognized as one of the big three unconquered infectious diseases, along with HIV/AIDS and malaria.

Joining that triumvirate has brought some success but TB remains the poor relation of the other two, especially HIV/AIDS, both with regard to domestic funding (US$ 11 billion for TB versus US$ 20 billion for HIV/AIDS in low- and middle-income countries in 2017) and international donor assistance (US$ 2.0 billion for TB versus US$ 9.9 billion for HIV/AIDS in 2021).[9] This distribution is mirrored in allocations made by The Global Fund, the principal financing agency for the big three, which split its 2023–5 budget as US$ 2.4 billion for TB and US$ 6.5 billion % for HIV/AIDS.[10] Elevated above other NTDs, TB membership of the global club of three has costs as well as benefits – exclusivity has reinforced TB separatism, where top-down (vertical) control programmes have not been effectively integrated into (horizontal) primary health services.

TB control has relied primarily on treatment with combinations of drugs (principally isoniazid and rifampicin) that patients must take for long periods without interruption, usually six months or more. The term 'treatment as prevention' was first used for antiretroviral therapy (ART) for HIV/AIDS, but that dual purpose—curing illness and stopping the transmission of infection to others—applies to any communicable disease where illness coincides with or precedes infectiousness, including TB. In effect, this is secondary prevention (averting severe illness and death) and primary prevention combined (stopping the spread of infection; Box 2.2).

Combination chemotherapy for TB is treatment as prevention: the drug combinations kill drug-sensitive bacteria quickly, stopping transmission and greatly reducing the risk of death. However, the decline in TB case incidence is slow (rarely more than 10% per year) because most populations carry a large reservoir of latent infection (roughly a quarter of the global population could be infected).[11] Furthermore, drug treatment programmes most effectively interrupt transmission when patients can be detected early in the course of illness but, given the slow onset of disease and non-specific initial symptoms, early diagnosis and treatment have been hard to achieve in many settings.[2,4]

TB treatment is one of 14 elements of the UHC service coverage index.[12] Over the period 2018–22, 34 million patients received treatment, 84% of the 40 million target. As made plain in Chapter 3, an effective health service must couple supply with patient access and demand, and yet about half (49%) of all TB patients faced catastrophic costs during treatment (total cost of treatment >20% of household income).[2] Putting TB in the context of health services, accessible care coupled with financial support are the key to timely diagnosis and successful treatment.[13]

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Just as the medical component of TB control has centred on drug treatment, so too has investment in research and development (R&D). In 2022, US$ 1.03 billion was spent on TB R&D, about the same as in 2021, but only half the sum pledged by world leaders at the 2018 UN High-Level Meeting on TB.[14] 34% of that total was allocated to drug discovery, including curative and prophylactic drugs. In line with industry priorities in general (Chapter 4), less was spent on vaccine research, only 14% in 2022, even though a replacement for the century-old BCG (Bacillus Calmette-Guérin) vaccine is much needed. Diagnostics, vital for stopping transmission and ensuring the best outcomes of treatment, also attracted 14% of the US$ 1.03 billion. R&D pipelines now contain a substantial number of candidate diagnostics, drugs, and vaccines, but fewer than desirable.[2] Operational research (OR)—the exploration of better ways to use existing tools—captured only 12% of funding in 2022.

The underfunding of TB research, coupled with the practical difficulties of patient diagnosis and treatment, help to explain why more people now die of TB than HIV/AIDS, and why TB deaths are declining more slowly than HIV/AIDS deaths (Figure 5.1(a)). They also explain why the rate of

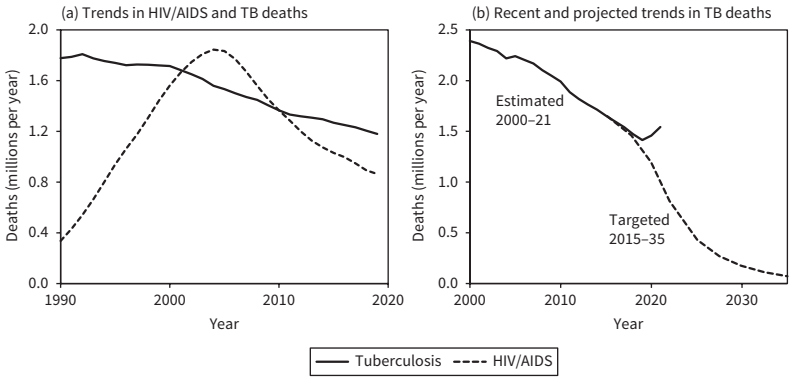

Figure 5.1 The challenge of TB control. (a) Global trends in deaths from HIV/AIDS and TB (excluding HIV-infected cases), 1990–2019 (before COVID-19). (b) Downward trends in the annual number of TB deaths, 2000–21, and the trajectory 2015–35 required to meet global targets for TB control. The uptick in estimated deaths 2020–1 is the consequence of COVID-19.

Source: data from World Health Organization, Global tuberculosis report 2023, Copyright (2023); Institute for Health Metrics and Evaluation (IHME), GBD Results Tool, Copyright (2023). Available at http://ghdx.healthdata.org/gbd-results-tool (accessed 3 January 2023).

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decline of TB before COVID-19, whether measured in terms of disease or death, was falling too slowly to meet global control targets by 2030 (Figure 5.1(b)). COVID-19 compounded the difficulties, disrupting routine TB services worldwide, causing approximately half a million excess TB deaths over the three years 2020–2022.[2]

The challenge of TB control, therefore, is to encourage investment in combating a persistent but low-risk, low-value hazard so as to accelerate the decline in illness and death. This chapter takes up that challenge, first by considering the various options for control.

The logic of prevention and cure

TB control is presently carried out with high coverage of a low-efficacy vaccine (BCG given to young children) and insufficient coverage of high-efficacy drug treatment.

Table 5.2 summarizes the pros and cons of methods for TB control, along a spectrum from prevention to cure. For illustration, assume that drug treatment of active disease halves the basic case reproduction number, R_0, from 2 to 1, by interrupting the transmission of infection (R_0, is the number of secondary cases produced one primary case introduced to an uninfected population; when $R_0 \leq 1$ the disease can no longer persist).[4,15] This is equivalent to vaccination with a transmission-blocking effectiveness of 50% (e.g. 80% of people vaccinated with 63% immunization efficacy in preventing infectious TB).

There is, however, a big difference between drug and vaccine in terms of the costs and benefits to patients and populations. The number of healthy people that have to be vaccinated is far greater than the number of TB patients who are given a course of chemotherapy: the lifetime risk of TB is of the order 0.1–1.0% per person (Table 5.2), and yet 80% of people (i.e. 80–800 times as many) must be vaccinated. There is a small chance that anyone vaccinated would have developed TB if not vaccinated; that small benefit must be set against the risk (usually very small) of harmful side effects. In contrast, drug treatment has direct and immediate benefits for TB patients and the communities in which they live, curtailing illness, averting death, and preventing the onward transmission of infection. A high-efficacy vaccine that can prevent infection (and therefore transmission) does not yet exist. so early diagnosis and treatment of active TB is currently the best form of primary prevention.

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Table 5.2 The costs and benefits of various options for TB prevention and curative treatment, in view of the hazards and risks

Population	Lifetime risk TB (%)	Goal of intervention	Type of intervention	Reduction of lifetime risk TB (%)	Reduction in R_0 (%)	Reduction in case fatality (%)	Costs (non-monetary)
No infection	0.1–1	Prevent infection	Vaccine	50	50	0	Moderate side effects 0.1% (if like BCG)
Latent infection	1–10	Prevent progression from latent to active TB	Mitigate risk	15	15	0	Variable
			Drug	50	50	0	Daily/weekly drugs 3–12 months Severe side effects drug 1%
			Vaccine	50	50	0	Moderate side effects 0.1% (if like BCG)
Active TB	100	Prevent severe disease or death; prevent transmission	Drug	0	50	90	Weeks/months of moderate/severe illness Severe side effects drug 1%

Note: these examples assume a R_0 of 2, a case fatality of untreated patients of 50%, a risk factor for TB with relative risk 2 (reduced to 1.5) and population prevalence 20%.

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BCG vaccine is effective mainly in preventing severe, non-infectious forms of TB in young children (meningitis and disseminated 'miliary' disease). It is sufficiently cheap (US$2–3 per dose) and safe (0.1% with moderate side effects) that it is widely recommended for children (Table 5.2).[16] In 2022, an average of 88% of one-year-old children received BCG in 155 countries.[17] But BCG does not effectively prevent lung disease in adults or stop the onward transmission of infection from adults with pulmonary disease. If a new, disease-preventing, transmission-blocking vaccine could be developed that is as cheap and safe as BCG, and efficacious in people of all ages against all forms of TB (including drug-resistant strains), it could radically change TB control, shifting the emphasis towards immunization as primary prevention.

Between preventive vaccination and curative drug treatment lies a third option, the treatment of latent infection; that is, targeting people who are already infected to stop the progression to active disease. Individuals who are carrying a latent *M. tuberculosis* infection have a 1–10% lifetime risk of progressing to TB disease (Table 5.2) so the number who must be treated prophylactically is 10–100 times the number who become TB patients. The traditional drug of choice, isoniazid, has high efficacy as a prophylactic, as well as being integral to regimens for treating active disease, but requires a lengthy course of treatment and has harmful side effects in around 1% of those treated.

In view of these trade-offs, is prevention worth the cost, effort, and potential harm, given the low risk but potentially high severity of disease acquired sometime in the future? This question is examined in more detail below, for new vaccines and for novel formulations and regimens of prophylactic and curative drugs.

But there are other ways to prevent infection or to reduce the risk of TB following infection, besides vaccines and drugs. These methods target one or more of the multiple 'risk factors' for TB, such as crowding, diabetes, HIV infection, alcohol and tobacco use, and undernutrition.[18]

The weakness of this approach is that most of the modifiable risks are not very risky: they increase the chance of acquiring infection or developing disease by a factor (relative risk) of 2–3. Mitigation brings large benefits only if a low-risk factor is very common, for example where a high proportion of people are undernourished, and if a programme of nutritional support can reach everyone who needs it. One option is to target people who are least well-nourished; that is more effective per person treated, but less effective in total (an example of Rose's paradox; Chapter 2). Compared

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with undernutrition, HIV co-infection presents a much higher risk for TB; so HIV treatment programmes can substantially reduce TB incidence, even when HIV prevalence is low.

Most of the personal and social risk factors for TB have other consequences for health. Therefore, the costs and benefits of managing them should be considered inclusively, from the perspective of the intervention rather than from the perspective of a specific disease (here TB; other examples are in Chapters 2, 6–8).[19]

All these aspects of risk and hazard, infection and disease, drugs and vaccines, have been absorbed within economic arguments for TB control, as follows.

Costs and benefits

Attempts to spur action on TB control by arguing that 'failure to end the epidemic is morally inexcusable and economically indefensible'[3,20,21] have been propagated for decades, with little success. First, a moral argument needs to be underwritten by a practical instrument—a law (stronger) or a code of conduct (weaker).[22] Such instruments are abundant but underused. On the long list are the Universal Declaration of Human Rights and the International Covenant on Economic, Social, and Cultural Rights.[23] Their establishment is a first step, but they will only succeed through persistent efforts at implementation and enforcement, based on an understanding of what is desirable and acceptable.

On the second, arguments rooted in economics have been somewhat more persuasive; the most compelling is reasoning based on real rather than supposed motives for choice. An effort to reinvigorate health financing during the 1990s led to the landmark 1993 World Development Report, *Investing in Health*.[24] That report identified TB control, based on combination chemotherapy, to be one of the most cost-effective of all health interventions. At the level of each patient treated, the cost per death averted was in the range of US$75–275 (1993 dollars). At the population level, adding in the extra benefit of interrupting transmission, the cost per death averted dropped about threefold to US$20–100.

These findings reinforced the WHO strategy for TB control launched around the same time (called DOTS, directly observed treatment, short course), and they have been frequently restated.[25,26] In practice, TB control programmes based on drug treatment are not quite as cost-effective as first

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estimates suggested. In 2019, the median cost per patient treated with drug-sensitive TB was US$860, within a wide range of US$100–10,000 across countries. Assuming that chemotherapy maximally reduces case fatality by 40%, from 43% to 3%, the median cost per death averted was US$2150, an order of magnitude higher than suggested by *Investing in Health* (ignoring currency inflation and any extra benefits of reduced transmission).

The extent to which TB treatment programmes—as they are currently implemented—can cut transmission is less than reflected in many epidemiological and economic analyses (giving e.g. the threefold advantage in *Investing in Health*). The onset of TB disease is typically slow and coughing patients usually become infectious before they seek diagnosis and treatment, transmitting infection to others. The difficulties of early diagnosis, and therefore of interrupting transmission, explain why TB case incidence has long been in slow decline (Figure 5.1).

The upshot is that TB control, as widely practised around the world, is cost-effective because it is moderately effective and not very costly. Greater effectiveness requires greater investment to overcome the dominant obstacles in each setting. In India, for example, the majority of patients have to navigate an unregulated market of expensive and inefficient, formal and informal, private health providers.[27]

The quality of private care can be improved through training, supervision, regulation, and subsidies; incentives for patient retention; nutritional support, and through collaboration with social welfare programmes. Many studies have shown that private practitioners will engage with public TB control programmes. But innovation and adaptation cost more money, so affordability could be more limiting than efficiency (cost-effectiveness).[28] For instance, one proposal to improve access to TB care in India, in both private and public sectors, would more than double TB service costs, even without resources for extra personnel and for making other essential health system changes. Realistically, however, this is the price that must be paid substantially to reduce the economic and health burden of TB on patients, their families, and society.[29]

Attempts to capture the benefits of TB control in monetary terms (as cost-benefit analysis), rather than as health gains (cost-effectiveness analysis), have made big claims about the return on investment, suggesting net benefits of $10 or more for each dollar spent.[30-33] Such analyses are vulnerable to two kinds of criticism. First, while the costs are cash spent, the monetary benefits are measured in terms of the value of a statistical life (VSL), which is typically estimated to be 100–150 times the average annual

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productivity of each person in any population, as measured by GDP. This large quantity supposedly reflects the willingness to pay (through revealed preference) for a reduction in mortality, but that willingness depends on who is paying and in what context (Box 2.1). Second, an estimated return on investment of 10:1 is a statistic that has little value in isolation. The point of putting monetary values on health and life is to allow a choice among different kinds of outcomes, other than health. The question, then, is whether 10:1 is a better return on investment than, say, building houses, roads, or schools. Besides the formal criticism, it is doubtful that such optimistic calculations have been a stimulus for action (Box 2.1).

Against this background, and in view of the persistently slow decline of the disease globally, the rest of this chapter investigates how to make TB control more effective: considering the perception of TB as a hazard; ways of amplifying the value of treatment as prevention; the potential for mitigating selected risk factors; the prospects for a high-efficacy vaccine; and the challenge of using prophylactic drug treatments more widely.

Evolution, if not revolution

Ebola with wings

TB is perceived to be a greater hazard when it behaves more like diseases such as Ebola; that is, when there are relatively sudden and unexpected increases in cases or deaths, with unpredictable limits (Table 5.1; Chapter 2). The fear of adverse change is reflected in the 'U-shaped curve of concern', a term coined when the steady downward decline of TB in the US was abruptly reversed during the 1980s (Figure 5.2).[34] The underlying cause was President Ronald Reagan's withdrawal of federal funding for public services, including health services, the consequence of cutting taxes. The funding cuts exacerbated poverty and overcrowding in urban areas and limited the capacity to prevent TB transmission in congregate settings, such as hospitals, prisons, and homeless shelters. The resurgence of TB was compounded by the unavoidable (at the time) spread of HIV infection, which predisposed people to TB by weakening their natural immunity to the disease.

The upswing in TB cases caused public alarm which drove political action, and government expenditure on TB control consequently rose sharply. The re-injection of funding, and a sense of crisis, allowed a rapid expansion of local health initiatives.[35] TB resumed its decline but has still not

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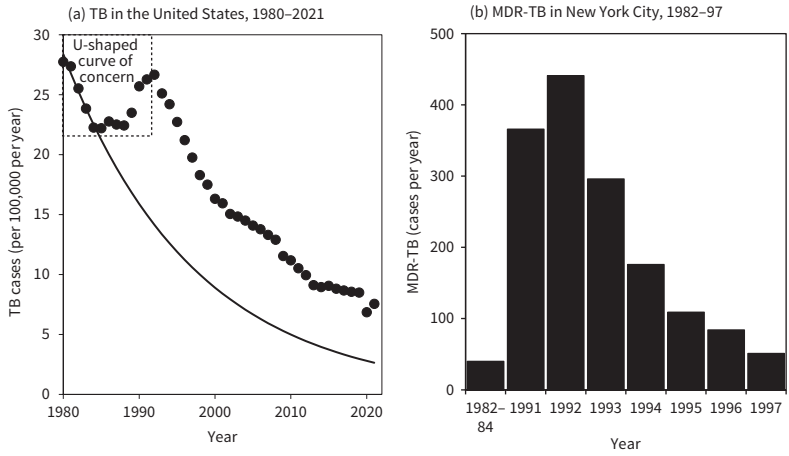

Figure 5.2 The temporary failure and incomplete recovery of TB control in the US between 1980 and 2021. (a) The national decline in TB was interrupted in 1985 (points), with consequences including (b) outbreaks of multidrug-resistant TB, like that in New York City. Since the 1985–92 failure (the upward arm of the 'U-shaped curve of concern', inset box), the decline in TB cases has still not recovered its previous trajectory.

Source: data from World Health Organization, Global tuberculosis report 2023, Copyright (2023); *N Engl J Med*, 333(4), Frieden TR, Fujiwara PI, Washko RM, et al., Tuberculosis in New York City—turning the tide, pp. 229–33, Copyright (1995), Massachusetts Medical Society.

recovered its earlier trajectory (Figure 5.2(a)). There were 243,000 excess TB cases between 1985 and 2018, 54% higher than the number expected (the gap between points and line in Figure 5.2(a)). These are the cases ordinarily prevented, and which should be counted, as a benefit of routine, uninterrupted TB control programmes.

The monetary cost was also large. Direct treatment costs of the excess TB cases between 1985 and 91 were US$ 340 million. Adding in the social and economic cost pushes the total up to $640 million.[36] And this was only up to 1991; the effects are still clearly visible today. The lesson from the 1980s is that gains in TB control are hard won and easily lost, and lapses in TB control carry a large and lasting penalty.

Besides the complications of TB as an AIDS-related illness, the failure of TB control in the US during the 1980s exposed another serious problem—outbreaks of multidrug-resistant TB (MDR-TB), most famously in New York City (Figure 5.2(b)). Suddenly, the cost of diagnosing and

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treating a TB case rose from hundreds to thousands of dollars, with more treatment failures and more deaths among patients. To highlight the threat, WHO characterized MDR-TB as 'Ebola with wings' (c.f. Table 5.1).[37]

When first-line drugs fail (isoniazid, rifampicin etc), second-line drugs such as fluroquinolones are added to treatment regimens. The use of a wider spectrum of drugs generates a wider spectrum of resistance. In 2005, the TB control community experienced their own manifestation of Disease X (Chapter 4): extensively drug-resistant tuberculosis (XDR-TB).[38] In 2006, South Africa was confronted with the triple hazard of HIV, TB, and XDR-TB: the spread of HIV was turning endemic TB into an epidemic, complicated by the emergence of strains unresponsive to first- and second-line drugs (Figure 5.3).[39,40]

The hazards of MDR-TB and XDR-TB, linked to a growing awareness of antimicrobial resistance ('superbugs'),[41] have been a fillip to TB control around the world, spawning books such as *Timebomb: The Global Epidemic of Multi-Drug Resistant Tuberculosis*[42] and positioning TB as a threat to global health security.[43]

New York City was able to contain MDR-TB because they intervened quickly, using early case detection to cut transmission and patient supervision to achieve high cure rates. Extra effort was taken to minimize the spread of infection in hospitals, homeless shelters, and jails.[44] The intervention was probably aided by the fact that multidrug-resistant strains of TB had not yet formed a large reservoir of latent infection in New York; most cases were due to recently acquired infection in the first major outbreak of MDR-TB. But the cost was high—US$ 1 billion to contain MDR-TB in New York City alone.

The New York experience with MDR-TB was proof of principle: drug treatment can, through cure and prevention, reverse the rise in cases and deaths from MDR-TB, even with the complications of HIV/AIDS.[45,46] Reversing the spread of drug-resistant TB is now more feasible than ever, following the development of new and more efficacious drug regimens.[47] During the 1990s, both the principle and the practice would need to be applied on a far greater scale, following the collapse of the Soviet Union.

Treatment for cure and prevention

The resurgence of TB in the US was overshadowed, from 1991 onwards, by the consequences of dismantling the Soviet Union (Figure 5.4). The health

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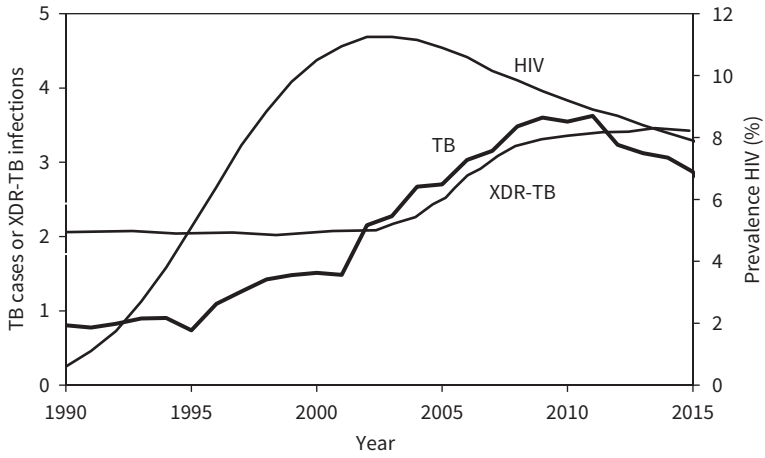

Figure 5.3 South Africa's triple hazard: the spread of HIV infection turned endemic TB into an epidemic, exacerbated by the emergence of XDR-TB. TB cases are routine notifications (100,000s); XDR-TB infections are estimates of the ($\log_{10}$) effective pathogen population size based on whole-genome sequencing; the HIV epidemic is tracked by prevalence in adults 15–24 years.

Source: data from World Health Organization, Global tuberculosis report 2022, Copyright (2022); *Proc Natl Acad Sci U S A*, 116(46), Brown TS, Challagundla L, Baugh EH, et al., Pre-detection history of extensively drug-resistant tuberculosis in KwaZulu-Natal, South Africa, pp. 23284–91, Copyright (2019), National Academy of Sciences; World Bank, World Development Indicators, Copyright (2023). Available at https://databank.worldbank.org/source/world-development-indicators (accessed July 11 2023).

effects of social and economic breakdown in former Soviet countries were amply illustrated by the renewed spread of TB: between 1992 and 2004, the percentage of excess TB cases linked to the loss of GDP growth (as an indicator of social and economic impact) ranged from 38% in Estonia to 70% in Russia.[48] The explosion of TB was just one element of a greater, unfolding health tragedy involving alcoholism and substance abuse; HIV/AIDS and sexually transmitted diseases; depression, anxiety, and suicide; and poor nutrition and environmental pollution. The death rate among Russian men aged 35 to 44 more than doubled between 1989 and 1994, taking six years off life expectancy.[49]

In response to the post-Soviet crisis, Estonia acted sooner than Russia, essentially following the WHO strategy for TB control, like New York City. Since 1996 in Estonia, case incidence per 100,000 people has been halving every eight years and the mortality rate every five years (Figure 5.4). The

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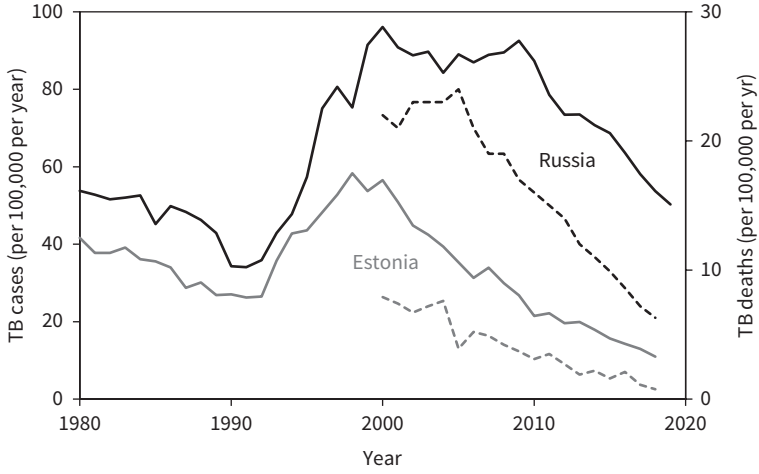

Figure 5.4 TB and the collapse of the Soviet Union. Russia (black) and Estonia (grey) suffered large surges in TB after 1991. Both countries have significantly cut TB transmission, case incidence (lines) and death rates (dashes) since 2000. Estonia acted sooner than Russia; Russia has not yet returned to the case incidence rate reported in 1991. TB notifications from both countries dropped in 2020 due to COVID-19, and are therefore not shown.

Source: data from World Health Organization, Global tuberculosis report 2023, Copyright (2023).

turnaround in TB control took place later in Russia, but since 2008 the case incidence rate has been halving every 12 years and the mortality rate every 6 years. The upshot is that it will have taken Russia nearly four decades to return to the level of TB incidence reported in 1991 and longer still to reach the level that would have been achieved by maintaining the downward trend of the 1980s. (Ukraine, a former Soviet Republic at war with Russia in 2022–24, has followed the same pattern as Russia).

The weakening of TB control programmes during the COVID-19 pandemic, reflected by the fall in reported cases and the probable increase in deaths (Figure 5.1(b)), threatens to have the lasting effects of temporary failure seen in the US and former Soviet countries, on a scale as yet unknown.

But the positive message from these examples is that early detection and treatment of TB can prevent deaths and reduce transmission if methodically applied and carefully adapted to local circumstances, in countries with

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a high or low burden of disease. High-burden India has struggled to cut TB transmission and incidence at a national scale; it has previously done so locally, notably during the 'model DOTS' project in Tiruvallur (1996–2006).[4] That project highlighted India's wider deficiencies in the organization of TB control (see next). England now has a far lower burden of TB than the global average (Figure 1.2), and extra effort accelerated the decline from 2011 onwards, pushing down the number of TB cases at an average of 7.2% per year during the decade to 2021.[50] This result was achieved mainly through interventions targeted to immigrants from high-burden countries: pre-entry screening and treatment of TB, plus the diagnosis and treatment of latent TB infection.[51]

Although TB control programmes have had special status within national health services, close links with preventive and primary healthcare can bring mutual benefits, of at least two kinds. First, patients usually seek care because they have symptoms (e.g. cough, fever, pain, weight loss) of unknown cause; differential diagnosis serves a broad function, identifying TB among other causes of illness. A long-lasting respiratory illness could be due to a different infection, asthma, chronic obstructive pulmonary disease or cancer, and chest X-rays for TB can reveal other conditions such as cardiomegaly (enlarged heart).[52] TB is causally linked to chronic diseases including diabetes and HIV/AIDS, where sharing resources—clinics, diagnostic laboratories, health workers, medical recording systems and pharmacies—can be more efficient.[53] Second, the particulars of TB case detection, diagnosis and treatment depend on, and contribute to, the other essentials of health service supply and demand: not just staff, equipment, and funding, but a system that provides access, continuity, equity, and quality of care.[54,55]

Plenty of lessons have been learned from successful and unsuccessful attempts to integrate (vertical) TB control programmes and primary (horizontal) healthcare.[56-60] The persistent under-performance of the former, coupled with the imperative to improve the latter should be an impetus to align both in the drive to achieve UHC (Chapter 3). Early diagnosis and treatment are at the heart of today's End TB Strategy (the current derivative of DOTS), but the intervention is bigger than the disease, with benefits for TB control, health services, and population health and wellbeing (Chapter 2).

And the intervention is not merely technical. Whereas, for example, DOTS listed 'political will' as a box to be ticked alongside 'diagnosis by

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sputum microscopy', ending TB requires a deep understanding of what motivates the choices made by politicians, patients and the public at large.

P is for prevention, much better than cure

So runs the first line of the children's PREVENTORIUM song (R is for rest in the open pure air, and so on).[61] Created in the US in the early 1900s, preventoria were institutions, mainly for pre-tubercular children—they were at risk of TB but did not yet have the disease (unlike sanatoria, which were for the sick). Before there were any drugs and vaccines, preventoria aimed to protect their patients from infection and disease, and stop the transmission of infection to others. They did this by means that were thought to be effective at the time: isolation, rest, and supervised exercise, nutritious food, physical and personal hygiene, and exposure to fresh air and sunshine, often in pastoral settings such as woods and forests, or near oceans, rivers, and lakes.[62]

Preventoria were conceived with a limited understanding of the factors that affect the risk of TB. Another century of epidemiological studies has led to the discovery of a wide range of biological, behavioural, social, and economic factors that affect the risk of TB. But most of these factors are relatively low risk and, even when highly prevalent, account for a minority of TB cases.[4] Consequently, reducing exposure to these factors across whole populations, including people at low and high risk, is not expected to have a big impact on TB.[63] This is why TB declined slowly in Europe and North America in the first half of the twentieth century, before the discovery of anti-tuberculosis drugs in the 1940s (Chapter 1).

There is, however, a more powerful argument for modifying these risks: all of them have broader consequences for health. This is why progress by and from TB control is closely monitored in the context of the SDGs—not only for health but also for poverty, hunger, energy, employment, and inequality.

People who are undernourished (low body mass index) are at three times the risk of TB, and undernutrition accounts for an estimated 1 in 5 cases of TB worldwide.[2] In areas of the world with a high prevalence of undernutrition, such as the central and eastern states of India, dietary improvements have multiple health benefits, in addition to reducing the risk of TB.[64-67] Better nutrition for children and adults restores energy deficits, increases resistance to other infectious diseases, and improves survival rates.

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Underweight is one form of malnutrition; overweight is another. Type 2 diabetes linked to high body mass index has become a global pandemic, currently affecting more than 400 million people worldwide.[68] Diabetes patients have a higher chance of developing TB (50% increase in risk), with the result that 360,000 TB cases and 40,000 TB deaths are attributable to diabetes each year.[2] Diabetes is not the main driving force for TB in any population: a comparison of the contrasting forces driving TB in India (high TB burden) and the Republic of Korea (low TB burden) found demographic processes to be far more important: population growth in India and population ageing in Korea.[19] But the link between TB and diabetes is strong enough to recommend screening both ways: diabetes tests should be part of the care provided to TB patients; and diabetes patients should be examined for, and educated about, signs of TB.[69,70] The joint care of patients with TB, diabetes, and other disorders linked to malnutrition potentially yields greater benefits per unit cost in integrated health services.

To remedy malnutrition—underweight and overweight—is not a quick fix for the TB pandemic, but would play a substantial supporting role.

Bigger and faster reductions in TB can be obtained by targeting factors that are high-risk for individuals, and highly prevalent in populations. The best example is ART used to treat HIV/AIDS in sub-Saharan Africa (Figure 5.3). ART restores immunity in general, and specifically against *M. tuberculosis*, prevents transmission of the HIV virus and halts the progression from TB infection to disease.[4,71] Whereas diabetes and undernutrition increase the risk of TB 2–3-fold, people infected with HIV have a 15-fold risk on average (see above). In Botswana, for example, the prevalence of HIV infection was 24% on average between 2003 and 2016 and an estimated 77% were attributable to HIV co-infection. Given the high risk and prevalence of HIV, ART is a powerful tool for TB control. The use of ART varied among African countries over the period 2003–16, and the percentage of TB cases prevented was closely linked to ART coverage (Figure 5.5). Over 12 countries, ART reduced TB incidence by 30%, 1.88 million episodes of illness in total.[72]

The differences in ART uptake between African countries lead to deeper questions about the motives for treatment and prevention—why the coverage of ART was higher, for example, in Botswana than in South Africa. Botswana's comparative success has a cultural and historical context, set by Tswana tribal leadership. Since independence in 1966, successive governments have invested in public institutions, policies, and services to tackle

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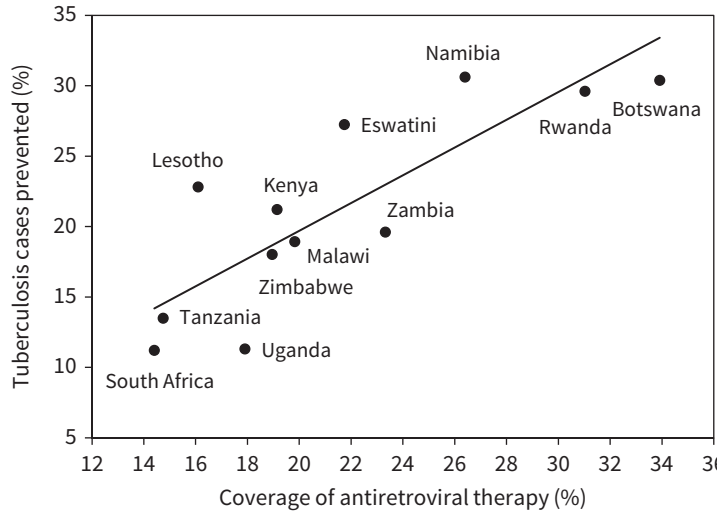

Figure 5.5 HIV treatment for TB control. Association between the coverage of antiretroviral treatment (ART) and the prevention of TB cases among people infected with HIV, for 12 countries in sub-Saharan Africa, 2003–16.

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ill health and poverty.[73,74] Diamond revenues, for example, financed education and infrastructure. Botswana was the first African country to provide ART free of charge to everyone who needed it.

In contrast, South Africa's earliest efforts to contain HIV/AIDS were hijacked by a dispute over whether AIDS was caused by HIV infection. South Africa was consequently slower to expand treatment, costing hundreds of thousands of lives,[75] but now has the largest number of people on ART (5.7 million in 2022), and the largest number of HIV-infected people on isoniazid preventive treatment for TB (4.0 million, see next). In 2015, South Africa also became the first country in sub-Saharan Africa to give full regulatory approval for pre-exposure prophylaxis (PreP), using ART to protect people from acquiring HIV infection, and therefore from TB too.[72] The wider lesson from these experiences in Botswana and South Africa is that public health practitioners generally benefit from understanding domestic, legal, regulatory and policy frameworks, and the cultural foundations of these norms.[76]

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From the perspective of TB, ART is drug treatment to manage a major risk. Other technologies are available to prevent TB directly: vaccines, and prophylactic drugs to neutralize latent *M. tuberculosis* infection, as follows.

Vaccines: preventing infection and disease

The high-efficacy vaccines developed for smallpox and polio opened the way to mass immunization, and global elimination and eradication campaigns. Such campaigns are not yet feasible for TB, given the limited efficacy of the BCG vaccine.

The development of a high-efficacy TB vaccine could be revolutionary, shifting the emphasis towards direct, primary prevention, reducing the need for combination chemotherapy. It is not yet clear whether such a vaccine could be created; even if technically feasible, it will take years to make, test, and distribute.

Endemic infectious diseases, such as TB and HIV/AIDS, persist partly because creating better tools for prevention—especially vaccines—is an immense biological challenge. None of the pathogens that cause these diseases (TB bacteria, HIV viruses) stimulate long-lasting immunity to first or subsequent infections, and few vaccines are more efficacious than natural immunity to infection (*Haemophilus influenzae*, a cause of bacterial pneumonia, and rabies are examples). In the development of TB disease, immunity actually conspires with infection to create lung cavities from which bacteria are expelled by coughing. And there are still no reliable markers of protective immunity to TB infection or disease.

Although investment in TB vaccine research increased little over the period 2015–21 (from US$81 to US$121 million per year),[77] coordinated international efforts have increased the momentum of vaccine discovery.[78] Among the most promising candidates is M72/AS01E, a 'subunit' vaccine that presents a specific, synthesized antigen to the immune system. In early (phase II) clinical trials, M72/AS01E safely prevented TB in 54% of adults carrying latent infections; in 2023, the vaccine moved into larger-scale (phase III) safety, efficacy, and effectiveness trials in African and Asian populations.[79] Set against the disappointing history of TB vaccination, M72/AS01E is a breakthrough.[80] However, this vaccine alone would not prevent a large number of TB cases quickly. An estimated 1.7 billion people carry latent infection,[11] and they contribute about 13% of all TB cases arising each year. M72/AS01E would cut that percentage to 6%. There

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is also the challenge of vaccinating a large number of adults, for whom (unlike children) there are no routine vaccine delivery mechanisms, even after COVID-19.

A new, highly effective vaccine is not imminent, but the pipeline is now fuller than ever before: 16 candidates were in clinical trials as of September 2022. It is immunologically easier to make a vaccine for SARS-CoV-2 than for TB. Nonetheless, it is a measure of the greater perceived threat of the COVID-19 pandemic that 50 vaccines had been developed and approved by at least one country within two years of the emergence of this novel coronavirus (by December 2022).[81]

Preventive treatment: avoiding harm and mitigating risk

In the search for a new mode of vaccination, the main challenge is to raise efficacy. The problem with prophylactic drug treatment is different: we already have high-efficacy drugs; the task is to improve uptake by reducing the cost, duration, and potential harm of treatment, as viewed by patients and health services.[82]

A course of isoniazid, taken daily for nine months, gives more than 90% protection against TB to people who are already (latently) infected with *M. tuberculosis*. The hitch is that few healthy people, who are generally at low risk of developing TB disease, are willing to take a drug daily for nine months, especially when there is a risk of harmful side effects.

The side effects of isoniazid include nausea, vomiting, and peripheral neuropathy, but the most severe is liver injury at a frequency of around 1% (higher in older people), with occasional fatalities. For comparison, the lifetime risk of TB among people carrying a latent infection is also of the order of 1%.[83] In other words, the chance of preventing TB is about the same as the risk of harmful side effects, a disincentive for prevention.

In view of the costs and benefits of preventive treatment, it is not surprising that the uptake is low: 2.2 million children under 5 years old, household contacts of TB patients, started preventive treatment over the period 2018–22, only 55% of the target of 4 million.[2] Preventive treatment for household contacts aged 5 years and above is even further from target: 2.0 million received treatment 2018–22, 10% of the 20 million eligible. The principal success has been for people infected with HIV: 11.3 million people in the years 2018–22, comfortably exceeding the target of 6 million. The reason for that

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success is clear: people living with HIV are at high risk of developing TB; a mix of TB preventive treatment and ART protects them against TB and the wider range of illnesses associated with AIDS.

Preventive treatment is likely to achieve higher coverage, with greater effects on TB epidemics, given shorter, safer, low-cost drug regimens, which can be targeted at those at high risk of disease or at high risk of transmitting infection to others. Research is generating shorter and safer regimens than isoniazid, for example a three-month regimen of once-weekly isoniazid plus rifapentine (in the same group of drugs as rifampicin) and a one-month regimen of these two drugs to prevent TB in people infected with HIV.[82,84,85] However, whether healthy people are willing to take a preventive drug even for one month, and whether health services are able to supply it, remains to be seen.

At present, the prophylactic treatment of latent infection plays an accessory role in TB control; slightly improved formulations could benefit more people, but prophylaxis is unlikely to be administered on a large scale to people at low risk of TB.

Summary

Stable, familiar endemic infections are rarely seen as health emergencies, even though they kill millions of people each year. But there are ways to remedy the neglect, here illustrated by tuberculosis. Because curative treatment is currently the best form of prevention, the immediate priority for TB control is early diagnosis and chemotherapy, aided by developing novel diagnostics (easier) and therapeutics (harder), and carried out in the context of primary healthcare. This reinforces three major goals of global health at the same time—strengthen primary healthcare, reach Universal Health Coverage (UHC), and put TB on a path to elimination. Other motivating strategies have supporting roles: highlight new dangers from old hazards, such as the emergence of multidrug-resistant strains; neutralize major risks for TB, especially co-infection with human immunodeficiency virus (HIV); and mitigate the large number of weaker TB risks that have co-benefits for other health conditions (diabetes, undernutrition) and for society more widely (homelessness, crowding). Vaccination is the ultimate, transformative, preventive tool for TB but awaits a high-efficacy companion or successor to BCG. Whatever the virtues of new technologies for TB control, none will succeed without understanding the means and

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incentives for implementing them, as illustrated by the roll-out of ART for HIV/AIDS and TB control in southern Africa.

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6
Chronic diseases

The burden of choice

> People pay for what they do, and still more for what they have allowed themselves to become.
>
> **James Baldwin (*No Name in the Street*, 1972)**

'And they pay for it very simply: by the lives they lead,' Baldwin added. He was only half right. What people allow themselves to become is usually the result of trading costs against benefits. And the price people have to pay is often not under their control.

Sound, general advice to consumers on healthy living—how to reduce the risk of heart disease, stroke, cancers, and diabetes—is uncontroversial among medical experts. Thus, 'Eat food. Not too much. Mostly plants.'[1] To which we can add, without much extra complexity: get enough sleep, exercise often, don't smoke, and drink alcohol in moderation. And follow all of this advice, not just part of it. There is unambiguous guidance for governments and businesses too.[2] All this information is widely available, although distorted by powerful manufacturers with a heavy sales pitch, and by the misinformed promoters of goop.

Getting good advice is one thing, following it is another. Because the immediate benefits of unhealthy choices appear to exceed the longer-term costs, neither the consumers nor the purveyors of toxic substances are inclined to self-restraint. Prevention is compromised because consumers judge that today's habitual, socially acceptable pleasures (alcohol, tobacco, salt, sugar, and others) outweigh the risk of poor health acquired incrementally over years, with the worst consequences expected in the distant, uncertain, devalued future (Chapter 2). That judgement is often made with

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a constraint: consumers have restricted choices, especially people with limited means.[3] There are examples everywhere: more than three million people in the UK live in areas where there are no shops selling fresh ingredients within 15 minutes by public transport.[4]

Consumers are trapped on the wrong side of a health dilemma. But some manufacturers are, too: if a healthier drink or food formulation is less tempting, or costs more to make and buy, a well-meaning producer risks losing out to competitors.

The upshot is that information about *what* to do is not enough. Consumers, governments, and businesses have to be motivated and enabled to do it.[5] In public health circles, 'behaviour' invariably refers to what consumers do, and yet the behaviours of governments, NGOs, and commercial suppliers are critical too. Governments, in particular, have the means to intervene between commercial supply and consumer demand, if they are inclined to do so. To counteract the social determinants of ill health, public health programmes must understand the underlying determinants of choice.

Chapter 4 focused on managing the risks of epidemics; Chapter 5 the hazards of endemic infections. This chapter highlights another key element of threat—time. The prevention of chronic, non-communicable diseases depends on the transactions among several parties, which determine the long-term health effects of short-term choices.

Nanny states

Governments, unlike most consumers, have access to the most accurate information about health risks and hazards. They know that the burden of illness on populations and health services, due to unhealthy behaviours, is certain, quantifiable, and already large, and that they must cover at least part of the cost. They also have at their disposal some of the most powerful preventive mechanisms—taxes (alcohol and tobacco) and regulations (e.g. mandatory salt limits in food, banning trans fat), plus subsidies and services, that can be used to encourage preventive methods (e.g. antihypertensive drugs to cut the risk of heart attack and stroke). The first of these, excise taxes on consumer goods (and 'bads') can actually raise revenue for governments. Taxing bads is also a way of relieving taxes on other forms of wealth, such as savings and income.[6]

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Adam Smith, founder of modern economics, was clear about the logic of state intervention. In 1776 he wrote, 'sugar, rum and tobacco are commodities which are nowhere necessaries of life … and which are therefore extremely proper subjects of taxation'.[7] But government proposals to tax and regulate harmful substances, as part of a strategy for prevention, invariably spark debate about the boundaries between individual and collective responsibility. Those who emphasize personal responsibility decry control by the 'nanny state'.[8] They are hostile to government restrictions on personal liberty, even on a small scale (e.g. behavioural 'nudges', Chapter 2). Those who favour intervention argue that the freedom to choose must be commensurate with individual and social responsibility. Those who are most disadvantaged, and who stand to gain most from intervention, are least able to choose. In this view, the notion of tax as the wage of sin ('sin tax') misses the mark, at least from the viewpoint of public policy: taxation weighs on the pocket, but it is also part of the social contract between citizens and government, an agreed way of giving consumers the freedom to make healthier choices. It is one way of creating the 'fully engaged' population imagined by Derek Wanless, aligning incentives for collective action (Chapter 3).[9] Progressive taxation, favouring those who are disadvantaged, is also a pathway to health equity.

Given the different preferences and powers of consumers, manufacturers, and governments, this chapter focuses on two of Adam Smith's unnecessary commodities: tobacco and sugar. The first step is to put both of these health hazards in a wider context—in relation to the burden and control of non-communicable diseases.

Non-communicable diseases and their causes

The great majority of people around the world now die from non-communicable diseases (NCDs) and injuries, rather than from communicable diseases. Among 57 million deaths in 2019, 42 million were from NCDs including, in rank order, ischaemic (coronary) heart disease (IHD); stroke; chronic obstructive lung disease (COPD); dementia; cancers of the trachea, bronchus, and lung; diabetes and road accidents.[10,11]

The number of deaths from all these causes (bar road accidents) is necessarily increasing year on year because the global population is still rising and everyone has to die of something. Trends in age-standardized death rates per person present an alternative, but complementary, global picture

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of gains and losses: COPD, IHD, lung cancer, and stroke are steadily falling from high levels while dementias and diabetes are approximately stable.[10,11]

In 2019, the risks underlying the causes of NCD deaths were behavioural (16.8 million deaths, e.g. alcohol, tobacco, sugar, salt, vitamins, and others), metabolic (18.0 million e.g. high blood pressure, blood sugar, body mass index), and environmental and occupational (8.2 million e.g. air pollution, exposure to carcinogens).

Linking these risks to causes of death, WHO's 4 ×4 framework is elegant in its simplicity.[12] Four groups of diseases (cardiovascular diseases, diabetes, chronic respiratory diseases, cancers) have been associated with four dominant, modifiable risk factors (tobacco, alcohol, diet, physical inactivity), where all diseases share all risks (except for chronic respiratory diseases linked mainly to tobacco).[13] The goal of this choice matrix is to make major health gains quickly by reducing a small number of common, modifiable risks (Chapter 2).

However, the 4 × 4 matrix does have several weaknesses. One is that the selected risks are all individual behaviours; the framework ignores environmental and metabolic risks. Another is that deaths from the four groups of diseases are attributable to more than four risk factors; and, reciprocally, the four risks contribute to deaths from other diseases. In this regard, there is no reason a priori to separate communicable from non-communicable diseases, which have shared risk factors. Moreover, the omission of certain major disease groups (e.g. mental disorders, oral diseases) and risk factors (e.g. sugar consumption, high blood pressure) has provoked debate about how to be more inclusive without loss of focus.[14]

Table 6.1 further explores the logic of choice matrices by examining the top five causes of death linked to the top five risk factors, revealing three main patterns. First, as in the 4 × 4 matrix, some diseases are linked to multiple risks, notably cardiovascular diseases and diabetes (columns 2 and 6); prevention is preferable, but the challenge of reducing multiple risks (though they are linked e.g. blood pressure and smoking) underlines the importance, too, of rapid treatment for acute cardiovascular events – heart attack and stroke. Second, deaths from the five groups of diseases are almost all of the deaths (column 1) that have been linked to the five risk factors. Deaths attributable to high blood pressure are almost entirely from cardiovascular diseases.[15] In contrast, tobacco and air pollution contribute to deaths from all five groups of diseases (rows 3 and 5). So prevention has large health benefits, and the benefits from controlling tobacco and air pollution are wide-ranging. Third, deaths from the other groups of

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Table 6.1 A 5×5 matrix of choice. Five major causes of death are linked to five major risk factors. Deaths are age-standardized rates per 100,000 people for 2019, and include communicable as well as non-communicable diseases. The Table was compiled first by ranking the top 5 risk factors, and then ranking the diseases linked to these risks (left to right). The risk factors are: high systolic blood pressure; tobacco use; dietary risks (mainly high salt, low grains, legumes, and fruits); indoor and outdoor air pollution; and high fasting plasma glucose. The first column gives the total death rates associated with each risk; the top row gives the total deaths rates due to each group of diseases. Shading highlights points made in the text.

				Groups of diseases		
Risk factors	**Total**	**CVD**	**Cancers**	**Chronic Respiratory**	**Respiratory infections**	**Diabetes**
Total	**453**	**240**	**125**	**51**	**49**	**38**
High blood pressure	**139**	128	0	0	0	11
Tobacco	**109**	39	32	23	8	3
Dietary risks	**101**	87	8	0	0	6
Air pollution	**86**	44	5	17	10	4
High blood sugar	**83**	48	5	0	2	26

Source: data from Institute for Health Metrics and Evaluation (IHME), GBD Results Tool, Copyright (2023). http://ghdx.healthdata.org/gbd-results-tool (accessed 3 January 2023).

diseases—cancers, chronic and infectious respiratory diseases (columns 3–5)—have important causes outside the top five risks, such as high body mass index for cancers.

A similar 5 × 5 framework based on years of healthy life lost (DALYs; see Box 2.1 for caveats) instead of deaths replaces one risk (child and maternal malnutrition instead of high blood sugar) and one outcome (maternal and neonatal disorders instead of chronic respiratory diseases), and narrowly excludes mental disorders (distinct from neurological disorders) and high body mass index. WHO's own expanded 5 × 5 framework includes mental disorders and air pollution.[12]

These frameworks have successfully drawn attention to major, modifiable causes of death: control blood pressure and blood sugar to reduce

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deaths from cardiovascular disease, stop tobacco smoking to prevent deaths from a wide range of ailments, and so on.

But they also conceal the potential for making substantial gains within major groups of diseases, notably among the diversity of cancers (column 3).[16] Some of the biological constraints and medical opportunities for cancer prevention are illustrated by trends among men and women in Scotland (Figure 6.1).

Around four in ten cancer cases in Scotland are attributable to known risk factors.[17] The risk of malignant skin cancer (melanoma) can be reduced by limiting exposure to ultraviolet radiation, and yet incidence rates have been rising since the early 1990s (Figure 6.1(a)). Deaths have fallen since 2010 because treatment has been more effective than prevention.

Lung cancer is the leading cause of preventable, premature death in middle- and high-income countries worldwide. Only 10% of patients with lung cancer survive for 10 years or more in the UK (England), so prevention is vital. For smokers, quitting is the best way to prevent cancers of the trachea, bronchus, and lung; in Scotland, incidence rates have been falling for at least three decades; mortality rates have fallen in parallel because the fatality rate remains high (Figure 6.1(b)).

The incidence rate of breast cancer, the most frequent cancer among women in Scotland, has been rising, and not only because the female population is ageing (Figure 6.1(c)). Unlike lung cancer, there is no single dominant, modifiable cause, so prevention depends on reducing multiple risks—tobacco, alcohol, high blood sugar, overweight, poor diet, and physical inactivity. But survival rates are improving, due to earlier diagnosis and more rapid and effective treatment.

The incidence rate of colorectal cancer is in slow decline, and mortality is falling a little faster (Figure 6.1(d)). These trends are likely due to a decline in exposure to multiple risk factors (which partly overlap with those for breast cancer), plus targeted screening and earlier diagnosis (e.g. removal of pre-malignant polyps at colonoscopies), together with advances in treatment.[18]

In short, while disease-risk matrices (Table 6.1) show how to make big gains against major groups of chronic diseases, biological details make clear the constraints and opportunities for prevention and treatment within groups, such as cancers. The next sections explore the constraints and opportunities for two major health risks—tobacco and sugar.

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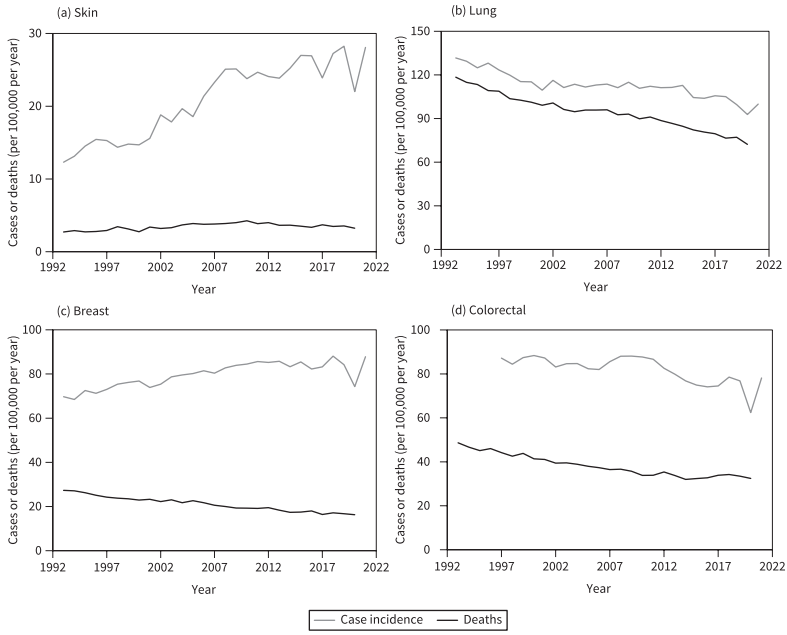

Figure 6.1 Trends in incidence and mortality (age-standardized rates per 100,000 per year) from four groups of cancers among men and women in Scotland (both sexes combined), 1993–2021. The cancers are specifically: malignant melanoma of the skin; trachea, bronchus, and lung; breast; and colorectal. Reported incidence rates were abnormally low in 2020 due to COVID-19.

Source: data from Public Health Scotland, Datasets, Copyright (2023). Available at https://www.opendata.nhs.scot/dataset?q=cancer.

Tobacco: legalized harm

Tobacco users trade short-term satisfaction for long-term harm. The satisfaction might be measured by the five trillion cigarettes still smoked each year; the harm by the 8 million killed by tobacco each year, or the 100 million who died during the twentieth century, about the same number as died of tuberculosis (Chapter 5).

Globally, the proportion of people who use tobacco is falling slowly (from 32.7% of people aged 15 years and older in 2000 to 20.9% in 2022, or 2% per year), and so is the number of smoking-related deaths per capita.[19] The total number of smokers is falling too, but even more slowly because

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of continued population growth (from 1.36 billion in 2000 to 1.24 billion in 2022, or 0.4% per year). Progress in taboacco control is halting rather than accelerating: the long-standing declines in global cigarette sales are stalling in every region of the world.[20] Smokers are mostly men (1.02 billion in 2022) and living mostly (63%) in the WHO South-East Asia and Western Pacific Regions (63%). If present trends continue, tobacco is expected to kill around one billion people in the twenty-first century.

Most smokers are aware of the risk of developing one or more chronic or fatal diseases, including bronchitis, emphysema, and more than a dozen forms of cancer. Some will also be aware that the life expectancy of regular smokers is shorter than for non-smokers and that smoking causes the majority of deaths (up to two-thirds) in people who continue to smoke (Figure 6.2).[21] If they are not aware, any private insurance company will make plain the risks: life insurance premiums for smokers are commonly 2–4 times higher than for non-smokers, reflecting the increased risk of death.

The reason why more than a billion people continue to smoke, suck, chew, and snuff tobacco is because it is addictively pleasurable. Even if there is a high risk of dying from a smoking-related illness, that outcome, for a young adult, is not immediate.[22,23] The health cost of smoking is therefore discounted.

A male smoker aged 30 years will lose 12 years of life on average if he continues to smoke. If he wants to quit, he may be enticed by the immediate health benefits. Within 20 minutes of the last cigarette, heart rate and blood pressure begin to fall. Within 12 hours, carbon monoxide in the blood drops to normal levels. After 2–12 weeks, blood circulation and lung function improve. After 1–9 months, coughing and shortness of breath subside. After one year, the risk of coronary heart disease is about half that of a smoker. After 5–15 years, the risk of stroke is the same as for a non-smoker. After 15 years, the risk of coronary heart disease is no greater than for someone who never smoked.[24] If he wants to go on smoking he may reassure himself that, provided he stops by the age of 40, his risk of dying from a smoking-related disease will be reduced by about 90% (compared with those who continue to smoke).[25,26]

The pros and cons of smoking have to be put in the broader context of livelihoods and lifestyles. Whereas health services usually consider smoking and its consequences separately from other health risks, individuals are more likely to place tobacco harms among life's other adversities. One sign of this perhaps, within a country or community, is that the prevalence of smoking tends to be higher among people who are more socially,

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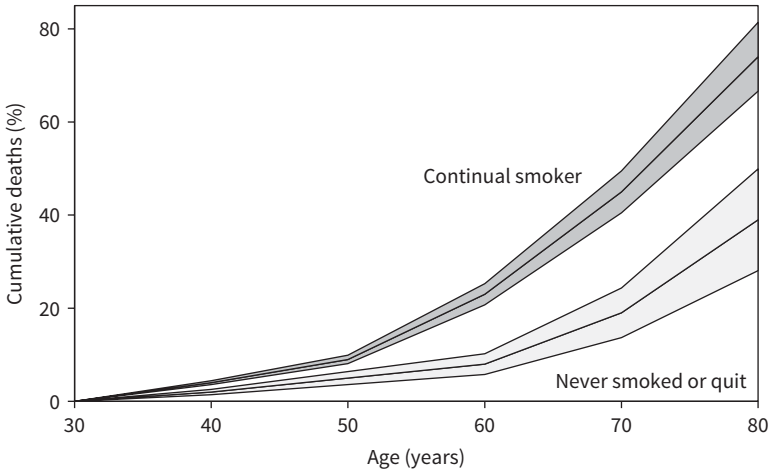

Figure 6.2 The certainty of tobacco harms. Cumulative risk of death (%) among men aged 30–80 years in the US who have never smoked (or quit by age 35) and who smoke continually. Shaded areas represent approximate 99% confidence intervals (proportionally the same as calculated for age 80). For smokers and non-smokers the cumulative risk of death increases exponentially throughout life but continued smoking approximately doubles the cumulative risk across all ages. Smokers should be in no doubt of the harms to health: they face a substantially higher risk of death after age 50, unless they quit, though they may discount the value of harms expected in the distant future.

Source: data from *N Engl J Med*, 368(4), Jha P, Ramasundarahettige C, Landsman V, et al., 21st-century hazards of smoking and benefits of cessation in the United States, pp. 341–50, Copyright (2013), Massachusetts Medical Society.

economically, and educationally disadvantaged, even though the cost of tobacco is a higher fraction of their income (Figure 6.3).[27-31] Tobacco magnifies health inequality via social and economic inequality.

As smokers become aware that tobacco is harmful, most do want to quit.[25,32,33] The burden of making that choice—shifting the balance of costs and benefits—can be lightened by helping them to do so. The measures known to be effective are the basis of The Framework Convention on Tobacco Control (the only modern international treaty in public health; c.f. IHR 2005 in Chapter 4), implemented via WHO's MPOWER strategy: Monitor tobacco use and prevention policies; Protect people from

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smoke; Offer help to quit; Warn about the dangers; Enforce bans on advertising; and Raise taxes on tobacco.[19,34]

The last of these mechanisms, taxation, is the most powerful, if governments have the will to use it.[35] Taxes bring the future into the present, giving consumers and manufacturers different choices. Consumers can pay a price today for the costs incurred to themselves and to society in future, or they can save the money, adopt healthier lifestyles now, and avoid the later costs. Manufacturers, if faced with reduced demand (e.g. for tobacco or sugar), might be inclined to reduce or modify production.

Tobacco taxes, increasing the cost to smokers, do cut consumption, deter young people from tobacco use, and raise revenue for governments wherever they have been applied around the world. On average, tobacco taxes that raise prices by 10% have led to a 4% reduction in overall tobacco use

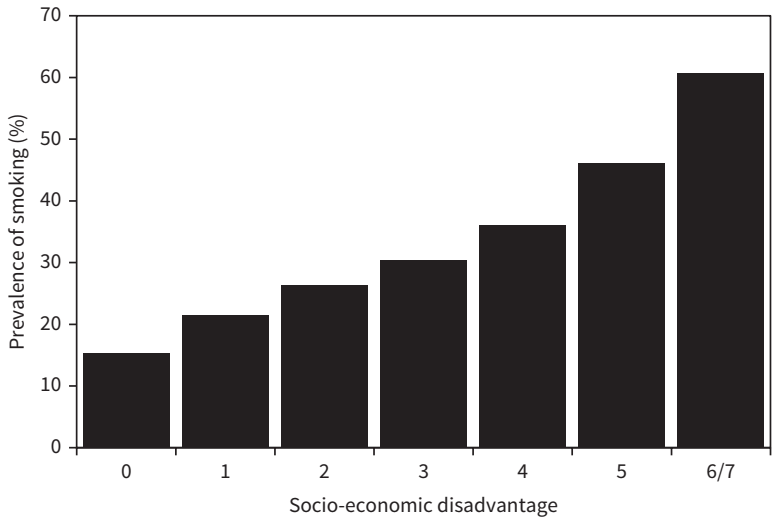

Figure 6.3 Variation in the prevalence of tobacco smoking with social and economic disadvantage (higher score on the horizontal axis). Although price increases deter tobacco use (Figure 6.4), smoking is most prevalent among people who are most economically disadvantaged. Data are from a survey of 88,000 adults aged 16 or over in England, 2001–8.

Source: data from *J Public Health (Oxf)*, 34(3), Hiscock R, Bauld L, Amos A, et al., Smoking and socioeconomic status in England: the rise of the never smoker and the disadvantaged smoker, pp. 390–6, Copyright (2012), Oxford University Press.

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in high-income countries and a 5% reduction in use in low- and middle-income countries.[6,36-38]

The government of France, for example, increased cigarette excise taxes substantially from the early 1990s onwards, tripling cigarette prices in real terms by 2010. Cigarette consumption dropped and so did the death rate from lung cancer (Figure 6.4).[36,39,40] There is an inverse relationship between death and taxes, but taxation alone will not eliminate smoking.

Taxing specific commodities, like tobacco, can rapidly deliver health benefits in any country, irrespective of national wealth. The Philippines raised tax on all types of cigarettes more than fourfold in 2012. Prices of the cheapest, most popular brands rose by more than 50%. Between 2011 and 2015 tobacco-tax revenues more than doubled, and the smoking rate among adults fell from 30% to 25%.[41] Tax revenues were used to help finance the expansion of health services in The Philippines.[25]

At national level, taxes paid by consumers tend to be more effective in countries where the price of tobacco makes up a larger fraction of income. Across the European Union, countries with a Gross National Income per capita lower than US$5400 were more responsive to taxation (high price 'elasticity') than those with incomes above this threshold.[42] Wealthier people are less sensitive to price but more aware of the risks to their health and the benefits of stopping. They are therefore more inclined to stop smoking by choice.

Despite exemplary successes, tobacco taxes are the least adopted tobacco control measure globally, due largely to disingenuous lobbying by the tobacco industry.[35] The Tobacconomics Cigarette Tax Scorecard uses a five-point scale to assess cigarette prices, including the share of cigarette taxes in retail prices, tax-driven changes in cigarette affordability over time, and cigarette tax structure. Progress has been slow. In 2020, the global aggregate score was 2.28, less than half of the maximum 5 points and not much bigger than 1.93 in 2014, with only eight countries scoring 4 or higher.[38]

Because taxes alone cannot eliminate smoking, MPOWER promotes other effective ways to reduce tobacco use. They include 'polluter pays' levies and corporation tax surcharges on industry profits from cigarette sales; banning pro-tobacco advertising and smoking in public places; and raising the minimum age at which people can legally buy tobacco, for example from 18 to 21 years.[43] The number of countries with at least one of six MPOWER measures in place has more than tripled, from 44 in 2007 to 151 in 2022; the number with two or more measures has increased nearly 10-fold—from 11 to 101 countries.[34]

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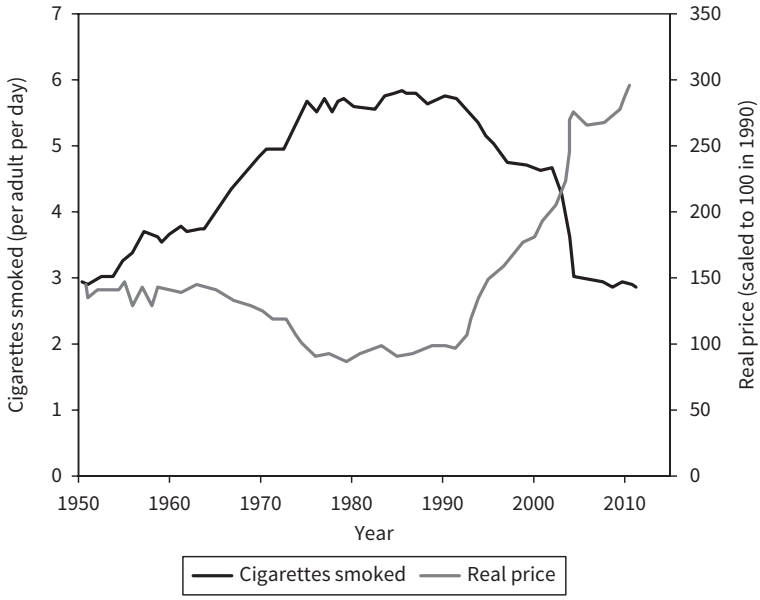

Figure 6.4 Changes in the inflation-adjusted price of cigarettes (scaled to 100 in 1990, grey line) and in cigarette consumption (of cigarettes per adult per day, black line) in France, 1950–2011.

Source: data from Jha P, MacLennan M, Chaloupka FJ, et al., Global hazards of tobacco and the benefits of smoking cessation and tobacco taxes. In: Gelband H, Jha P, Sankaranarayanan R, et al., [eds], *Cancer Disease Control Priorities*, third edition, pp. 175–93, Copyright (2015), World Bank.

Most of the instruments used to discourage smoking—prohibitions, taxes, regulations, and cautions—are prevention by punishment and threat. They warn of future health lost rather than advertising the benefits of good health gained. A complementary approach is to offer carrots while wielding the sticks. E-cigarettes (vapes) are a relatively cheap and probably safer way to help some adult smokers who want to quit.[43-45] The drawback is that they are far from completely safe: e-cigarettes contain multiple hazardous chemicals that are potentially harmful to health, short- and long-term.[46] And they endanger children who are at risk of nicotine addiction and respiratory illnesses, and of graduating from vaping to smoking.

The outcome of the confrontational, triangular relationship between tobacco consumers, governments, and manufacturers is in the balance. Public health battles have been won but not the war: consumers have access

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to effective methods to stop (or not start) smoking; governments have enormous powers that they are often dissuaded from using; and manufacturers are selling ever more cigarettes, e-cigarettes, and other devices to encourage and maintain nicotine addiction. The COVID-19 pandemic was also a setback for tobacco control, as governments diverted their attention to a more acute crisis.[38]

Sugar: excess pleasure

In *The Saccharine Disease* (1974), T.L. Cleave considered how members of the public might balance the pros and cons of eating and drinking refined carbohydrates. He guessed that 'in prevention, very little; in treatment, quite a lot; in short, people will go on enjoying themselves till they get hurt'.[47]

Humans are living in a calorie trap, ensnared by physiology and society. People like sugar, and manufacturers compete to sell it to them cheaply. The body efficiently stores excess energy as fat, and then obstinately defends its removal.[48] Like tobacco, sweet food is a source of instant gratification. Unlike tobacco, sugar is not harmful per se, only when consumed in excess, especially as part of a poor diet. Eating it is not socially unacceptable, nor does it pose an immediate hazard to others. Because sugar is toxic only in quantity, its consumption is harder to control than tobacco.[49]

Today, ultra-processed foods (UPF), including sugar, have infiltrated every aspect of diet at every stage of life, from infancy onwards, and the consumption of UPF has been linked to adverse effects on mental, respiratory, cardiovascular, gastrointestinal, and metabolic health, and on cancers and mortality.[50,51] More than a quarter of adults are obese in every country of the world, and no nation has significantly reduced obesity in recent decades.[52]

Sugars added to food and drinks by producers and consumers, plus sugars naturally present in honey, syrups, and fruit juices, push up the energy content of what we eat. By and large, consuming free sugar is harmful to health. And unnecessary: for most people, enough sugar is available in fruit, vegetables, and whole grains, which provide a wide range of nutritional benefits.

A high sugar intake, especially fructose, increases the frequency of metabolic conditions that are risk factors for other diseases—high blood pressure, high body weight, ectopic fat accumulation (around the liver, heart,

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and pancreas), elevated serum lipids and cholesterol (low-density lipoprotein), and obesity. These risks are precursors for cardiovascular and liver diseases, cancers, and type-2 diabetes. Consuming free sugar accelerates tooth decay (especially for children), and tends to lower the quality of a diet overall by providing energy and satisfying appetite while leaving out other essentials—protein, fibre, minerals, and vitamins. During the 1970s in the US, the growing use of high-fructose corn syrup as a sweetener, and the growing popularity of processed food (which replaced home cooking with fresh ingredients), coincided with a marked rise in obesity, type-2 diabetes, and cardiovascular disease.[53-60]

From this body of evidence it is clear that reducing excess energy intake from sugar, especially in the form of sugary drinks and snacks, can reduce body weight, blood pressure, and cholesterol, and the conditions linked to these risk factors, notably cardiovascular diseases and type-2 diabetes.[57,61-64]

Given all the evidence, WHO recommends that less than 10% of energy input comes from added sugar, and preferably less than 5%.[65] How can that be achieved?

Cutting out free sugar is just one way to improve diet and health, to be combined with others, dietary and medical.[66,67] On therapeutics, revolutionary new drug treatments for overweight and obesity—the glucagon-like peptide 1 (GLP-1) agonists, such as semaglutide—stimulate insulin release to normalize blood glucose concentration, slow gastric emptying, and promote and prolong satiety signals from gut to brain. That reduces appetite for all foods, including those containing sugar.

Initially developed as treatments for type-2 diabetes, GLP-1 agonists are now blockbuster drugs that cause extraordinary weight loss.[68] And weight loss induced by GLP-1 agonists is linked to a growing number of other health benefits, besides type-2 diabetes—lower blood pressure, lower risk of obesity-associated cancers, less liver fat (non-alcoholic fatty liver disease), better heart health, and the control of weight gain caused by anti-HIV medications. But these drugs carry plenty of risks too. One of them is that weight-loss drugs could discourage the adoption of balanced (low-sugar) diets which, irrespective of body weight, are the basis of metabolic health.

Most consumers of unhealthy foods want help to resist temptation, as do cigarette smokers. For sugar-sweetened drinks, the forms of help known to be effective include price increases in restaurants, shops, and leisure centres; government food benefits (e.g. food stamps) that exclude sugary drinks; promotion and better placement of healthier drinks in supermarkets; and

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schemes to make low-calorie drinks, especially water, more readily available in homes, schools, and restaurants.[69]

Legislation—for taxes and regulations—is the best way to implement these mechanisms of support. Sugar taxes can reduce consumption and raise revenue, provided they are carefully calibrated. The focus has been on taxation to deter the consumption of all forms of sugar-sweetened beverages (SSBs). Among the variety of taxation methods, excise taxes are preferred from a public health perspective because they raise the relative price of SSBs compared to other products and services in the economy, making SSBs less affordable. Tiered tax mechanisms encourage manufacturers to reformulate beverages with lower sugar content beneath tax thresholds, so they can pay less tax or no tax at all, but are complex to administer. Some nutritionists prefer to tax sugar itself rather than, say, sugary drinks by volume: the tax should be proportional to the harm caused. In any event, tax schemes should be designed jointly by finance and health policy makers, and in consultation with food industry professionals.[70-72]

By mid-2022, 118 tax schemes were in operation globally, including 105 national and 13 subnational taxes, mostly excise taxes (88% of schemes), and covering half (51%) of the world's population. Remarkably, 67% of people in low-income and 73% in lower-middle-income countries were covered by national SSB taxes, but only 29% in higher-income countries. More than half of the excise taxes worldwide applied tiered rates, with tiers more commonly defined by beverage type than by sugar content.[73]

In England, around 10% of children aged 4–5 years and 20% of children aged 10–11 years are obese (BMI >95th centile on UK growth charts). As one approach to tackling childhood obesity, the UK government introduced the Soft Drinks Industry Levy (SDIL) in April 2018.[49] Drinks with ≥ 8 g sugar/100 mL were taxed at £0.24/L (high tier), and drinks with ≥ 5 to < 8 g sugar/100 mL were taxed at £0.18/L (low tier). Within a year, the purchased volume of high-tier drinks fell by 38% and the sugar content of these drinks by 43%. The reductions in volume and sugar content for low-tier drinks were 86% and 88%, respectively. These gains were probably made because manufacturers reduced the sugar concentration of drinks, and consumers switched to lower-sugar alternatives. SDIL apparently had an even bigger effect: children and adults reduced the consumption of free sugars from other foods and drinks, not merely from soft drinks alone.[74]

Health benefits from SDIL are expected but not yet proven; however, the levy has been associated with a reduction in obesity among girls aged 10–11 years, especially those from the most deprived backgrounds (but not

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boys, and not younger children).[75] Among other positive effects, we can expect to see improvements in dental health, especially among children.

If taxes on sugar-sweetened drinks are effective, why not tax sugary snacks too? High-sugar snacks (confectionery) usually provide more free sugar and energy than sugar-sweetened beverages.

Consumers are sensitive to price increases in foods, including sugar-sweetened foods, just as they are for drinks. Countries, including Mexico, Finland, and Hungary have introduced taxes on sugary snacks, among other unhealthy foods. In Mexico, all 'non-essential' foods with 275 or more kcal/100 g are taxed at 8%, including confectionery such as biscuits, chocolate, and cereal bars. The effect was to reduce purchases by 5–6%, with greater effects among those who habitually bought more sweets.[76] Taxes on foods high in salt, sugars, and fat had been implemented in 29 countries by 2022.[77]

Whereas taxation and regulation strongly influence supply and demand, guidelines, and voluntary codes of conduct for manufacturers and consumers are largely ineffective.[78-80]

Public Health England (now the UK Health Security Agency) developed a voluntary programme in which manufacturers would cut sugar in snacks, with poor results.[81] Commercial producers were asked to reduce the sugar content of a range of foods by 20% over the period 2016–20. The net reduction in sugar content was only 2.9% after two years and the consumption of some products was pushed up by promotional offers and advertising. Some food manufacturers actually increased the sugar content of their products.

SDIL has been unusually forceful among UK government policies on obesity. An analysis of 14 government strategies published between 1992 and 2020, including 689 different policies, found that most were proposed in ways that made them hard to implement; they were light on intervention and placed heavy demands on individual choice.[49,82] In this regard, UK governments appear to be in tune with public opinion—most people see tackling obesity primarily as an individual problem. But they also believe that government and industry should provide at least some help: there is majority support for bans on advertising unhealthy foods on TV and online; bans on retail promotions of unhealthy foods; taxing producers of foods high in fat, salt, and sugar; and using tax revenues to fund fruit and vegetables for low-income families.[49,83]

The mounting costs to health services of medical treatment for chronic and other diseases are becoming unaffordable, especially in high-income countries, while more preventive care would cost a small fraction of public

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health budgets (Chapter 3). Whether these economic pressures will sway public opinion and overcome political resistance remains to be seen, in the UK and in other countries.

Preventing illness, promoting health

Preventing illness and promoting good health should be complementary—the net benefits are health gains made plus losses avoided. Diet and exercise are two examples.

Simple messages that promote healthy food choices are generally ineffective.[84] Adjusting the cost of food has greater leverage. Cash incentives and subsidies encourage healthy eating: with lower prices, more people choose to buy, for example, fruit and vegetables, provided the price reductions are large enough (in one study, 10–15% or more).[85-89]

Wealthier people are less reliant on subsidies, and some are willing to pay higher prices for healthier foods: experiments carried out mostly in high-income countries have found that people who are older (>60 years), obese, or more physically active are ready to pay more for foods with reduced fat, more wholegrains, and extra fruit and vegetables.[90] In the same experiments, younger people with healthy weight and higher levels of income and education were not willing to pay more. The wide range of studies on taxes, subsidies, cash, and health foods shows that pricing instruments work, but need to be fine-tuned to the means and motives of consumers.

Strong incentives are also needed to combat physical inactivity, a leading cause of mortality worldwide.[91,92] Although sedentary populations are notoriously immovable,[93] there are notable successes. Parkrun is a 5 km weekend run launched in the UK in 2004, which now takes place at more than 2000 locations in 22 countries worldwide.[94,95] Organized by volunteers, it has been successful in getting people active, probably because it offers a variety of benefits, which offset the comparatively low cost and effort of joining in. Parkrun is a means of health promotion but it is as much a social as a sporting event. Group running satisfies a range of motivations, from weight loss to speed gain, from getting out in the park to meeting friends at the weekend. There are strict but simple rules, which are applied everywhere, from Siberia to Soweto to San Francisco; and even in prisons in Australia, Ireland, and the UK. There is no need to be a hard-core runner; almost anyone can complete the short course—running, jogging, or walking. Parkrun is free to enter, takes place in the open air and under natural light,

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and is not tied to an indoor gym subscription. There is no upper time limit, no upper age limit, and there is no need for special equipment. Parkrun is sociable but also personal: each participant gets a time for the course, or a record of volunteering. They can use their own data to set benchmarks for improvement and compare their performances with friends and competitors. But only if they want to.

Mixing incentives and disincentives, deterrents to car use go hand-in-hand with the provision of convenient, safe walking and cycling paths in towns and cities. However, the promotion of active lifestyles for better health invariably has a wider context. Helsinki's successful active transportation programme—limiting car use in the city and coupling public transport with easier ways to cycle and walk—was not driven primarily by health, but by a vision of how the city can be made more liveable—aesthetically appealing, safe and easy to get around.[96] This is another story of Health in all Policies (Chapters 2, 3, 7), and of the Sustainable Development Goals. In Helsinki, as elsewhere, health has to make its claims among all other government priorities. Complementary rather than competing claims tend to be more successful.

Summary

Many consumers of tobacco, sugar and other causes of chronic diseases are trapped in a world of limited options (nothing but junk food), hard choices (tobacco addiction), and few resources (economic hardship), temporarily eased by postponing (discounting) the personal costs of future illness. Consumers are ultimately responsible for 'behavioural' risks to their health, but the behaviours in question are also those of manufacturers and governments. The burden of choice on consumers is lighter when shared. Governments, in particular, have the means to intervene between commercial supply and consumer demand. The most effective instruments of government are the most forceful—taxes and regulations—especially for the control of single, major causes of illness such as tobacco and sugar. In practice, governments under pressure from manufacturers tend to under-tax and under-regulate harmful commodities, so other enticements are needed too. Empirical studies show that campaigns to improve health (better food choices, greater physical activity) can complement those to prevent disease, especially when the joint benefits for health are large. The greater task, however, is to empower public demand for government action that favours

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health, and disempower commercial interests that drive the consumption of sugar, tobacco, and other causes of chronic disease.

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7
Sanitation

The culture of conveniences

> Water is life, sanitation is dignity
> **UK Department for International Development (2007)[1]**

Water and life trump sanitation and dignity, with major consequences for health. Despite thousands of years of toilet culture and technology, the great majority of people alive today do not have access to safe sanitation. The challenge of sanitation is to align the benefits for health with personal and social preferences for toilet use and hygiene, while exploiting other advantages for agriculture, energy, education, environmental protection, housing, and flood protection. Getting the most out of sanitation requires cooperation among many kinds of providers and users—individuals, communities, businesses, financial donors, and governments—who have different needs in different settings. To make a compelling case for investment in sanitation, economic evaluations should go further than conventional cost–benefit analyses, which typically ignore the cultural constraints and neglect most of the social benefits. In that wider context, this chapter explores the motives, constraints, and opportunities for investing in safe sanitation pursuing 'not merely the absence of illness', but also the quality of life that is integral to personal, social, and economic wellbeing.

The bottom three billion

A 2007 survey for a top medical journal (*BMJ*) voted sanitation the greatest medical advance since 1840—ahead of antibiotics, anaesthesia,

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and vaccines—even though health is just one of sanitation's many benefits (Chapter 1).[2] The enormous value of sanitation, for the health of individuals, families, and communities, has been understood for millennia (Chapter 1). And yet the state of the world's toilets and sewers today is parlous. Every country has signed up to the goal of achieving 'access to adequate and equitable sanitation and hygiene for all and ending open defecation' by 2030, in line with the Sustainable Development Goals (SDG 6.2) but, without intensive effort, many will fall short of that target.

In 2022, 57% of people globally lived in households without access to a 'safely managed' sanitation system.[3] That means that 4.6 billion people had access, 3.5 billion did not. That is, they did not have exclusive use of a health-safe system that separates excreta (and the pathogens it carries) from humans and the environment, such as a flush toilet linked to a piped sewer, septic tank, pit latrine, or a composting toilet.[4] Among the 3.5 billion, an estimated 419 million people were still practising open defecation. At the same time, the world's most fortunate—the top billion—had the luxury of defecating into water that is almost clean enough to drink.

Sanitation has been improving around the world, but slowly. Between 2015 and 2022, access to safely managed sanitation increased by an average of about 1% of the human population per year. In 2022, only 17 countries were on track to achieve universal access (>99% coverage) by 2030, 84 were progressing too slowly, and 24 were going backwards (coverage falling).

Comparing progress in the provision of drinking water (faster) and sanitation (slower) points to the effects of different incentives driving the two goals. In 2022, nearly half (45%) of all countries were on track to achieve national drinking water targets by 2030 but only a quarter of countries were on course to meet targets for sanitation.[5]

Although drinking and defecating are both daily necessities, a safe water supply is needed every day but safe sanitation is not. Water typically comes from a central source (spring, well, river) that must be cooperatively managed, whereas there are multiple sites to defecate in the environment. Open defecation is not only possible, particularly in rural areas of Africa and Asia, but also socially acceptable, and there is a big step from ending open defecation to acquiring even basic sanitation facilities that are exclusive to households in a community. Public willingness to pay for sanitation and wastewater treatment is consequently lower than for the provision of drinking water, and unit costs are usually higher.[6] Water is talked about openly, in terms of water purity, wellbeing, and quality of life, and attracts public champions; defecation, like other private bodily functions, draws abundant euphemisms but few public advocates.[7] Sanitation also

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commonly loses out to water when setting policy and budgetary priorities, particularly when controlled by water ministries.[1]

The slow progress in sanitation is at odds with numerous economic evaluations which conclude that sanitation is good value for money. A 2012 World Health Organization (WHO) study calculated that every US dollar invested in sanitation would deliver a return of US$ 5.50 (range US$ 2.8–8.0 across nine regions of the world) in lower health costs, fewer premature deaths, and greater economic productivity.[8-12] Such favourable rewards are intended to encourage investment by governments and international donors but, judged by the slow progress since 2012, they have been less persuasive than expected. There are two possible reasons: the costs of safe sanitation are too high; or the benefits are too low. Both costs and benefits must be broadly defined—beyond money.

First, the costs. Basic water, sanitation, and hygiene (WASH) services cost only $0.6 per person each year in the least developed countries, or 6% of government health spending in these countries. The challenge lies in rapidly scaling up investment to meet SDG targets for water and sanitation in less than a decade (by 2030). A 2016 analysis found that those meeting targets would need a tripling of capital investments, to which must be added the operations and maintenance costs that are vital for service continuity.[13] Surveys carried out in 121 countries in 2022 found that more than three-quarters had insufficient funds to implement national WASH plans, and more than 80% had too few trained professionals to manage sanitation and drinking water systems. The financial burden on households was high: governments contributed 29% of WASH funding, and households 61%. And while domestic funding is stretched, 'official development assistance' (foreign aid) for WASH has been going down.[5,14] The present funding gap is therefore huge; the SDGs may demand much more than governments, households, and aid agencies are willing or able to afford.

Second, the benefits. The WHO study calculated the major economic value of sanitation to be in time savings (81%), augmented by lower healthcare costs (8%), and greater longevity (6%) and labour productivity (5%).[10] But many other potential benefits were excluded, as the authors made clear: for agriculture (nutrients for soil fertility), energy (excreta recycled for fuel), education (school attendance), environment (water reuse, safety, and security), housing (sanitary assets), infrastructure (access roads, flood protection), and quality of life (personal safety, convenience, dignity, gender equality).[10] All of these assets, if they can be acquired, suggest that the potential benefits of sanitation have been undervalued. Sanitation could yield more than a fivefold (average) return, depending on the technology

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(pit latrines, septic tanks), making it still more competitive as an investment for development (with the usual caveats on benefit/cost ratios; Box 2.1).[10]

There are, however, important qualifications to the idea that sanitation can deliver large benefits if only the costs are affordable. One of these is that the perceived costs, benefits, and minimum requirements for sanitation, which govern choice, differ among individuals, communities, businesses, donors, and governments, all of whom have the power to influence decisions. Unless sanitation is valued by all who have a stake, it is not likely to succeed. The true return on investment could, in practice, be anything from negligible to enormous, depending on the degree of cooperation.

With that background, the rest of the chapter considers the value of sanitation to everyone involved: with respect to individual and population health, including the prevention of epidemics; in satisfying personal preferences and social norms for toilet use and hygienic behaviour; in gaining strength from cooperation, locally and nationally; and in contributing to sustainable development.

Dialogue on diarrhoea

Safe water and sanitation prevent exposure to faeces, mainly the faeces of other people or animals, which are sources of new infections with an array of disease-causing pathogens (Chapter 2).[15] Among them are bacteria—*Vibrio cholerae* (cholera), *Cryptosporidium*, *Shigella* (dysentery), enterotoxigenic *Escherichia coli* (*E. coli* is also a marker of environmental contamination with faeces), *Salmonella* (typhoid), and *Chlamydia* (blinding trachoma), some of them now resistant to antibiotics. There are viruses—adenovirus (conjunctivitis), polio, hepatitis A, rotavirus; parasites—the soil-transmitted helminths *Necator* and *Ancylostoma* (hookworms) and *Ascaris* (roundworm); snail-borne *Schistosoma* (bilharzia); and fungi such as *Tinea* (ringworm). Open drains and sewers also provide breeding sites for the mosquito vectors of *Wuchereria* (filarial worms), *Plasmodium* (malaria) and West Nile virus, among others. Unsafe hygienic practices expose people to bacteria (*Haemophilus influenzae*, *Streptococcus pneumoniae*) and viruses (influenza, SARS CoV-2) that cause acute respiratory infections. As well as causing specific illnesses, infections contribute to, and are predisposed by, various forms of undernutrition (stunting, wasting, vitamin and mineral deficiencies), losing school time for children, cutting the productivity of working adults, and shortening life expectancy.[16,17]

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Given this parasitic onslaught, and slow progress towards SDG targets, the burden of illness attributable to unsafe sanitation remains large: in 2019, around 1.4 million deaths were linked to unsafe WASH, the majority (>1 million) due to diarrhoeal diseases. Through exposure to infection, unsafe water and sanitation accounted for 69% of the burden (morbidity and mortality) of diarrheal disease, 14% of acute respiratory infections, 10% of undernutrition, and essentially all disease due to soil-transmitted helminths.[18,19]

This analysis, plus the evidence from field studies suggests that clean water, safe sanitation, and improved hygiene could prevent a large fraction of this disease burden.[20] But for sanitation to succeed, supply (from providers) must meet demand (from users). Although the risk of infection from unsafe sanitation is persistently high in many low-income countries, the risk of a severe or fatal outcome is small. Even in South Asia and Sub-Saharan Africa, where children under five years old typically suffer 2–3 episodes of diarrhoea each year, most episodes are mild and self-resolving; less than two in a hundred are severe and case fatality rarely exceeds two in a thousand.[21] In these settings, childhood diarrhoea is sometimes viewed as a chronic normal (like tuberculosis, Chapter 5), an accepted and low-value part of everyday life, albeit with occasional outbreaks of severe diseases such as cholera (see next).

If individual people (low risk of severe disease) and public health authorities (high disease burden) attach different values to sanitation, and are also presented with different costs, these differences may need to be resolved to encourage collaboration.

Both individuals and public health authorities are also usually aware that there are alternative methods of prevention (vaccines) and cheap and effective treatments for diarrhoea (oral rehydration therapy)—in principle, these are disincentives for prevention through sanitation and hygiene.

Sanitation in the time of cholera

John Snow's famous investigation of cholera has forever linked the disease with a failure to provide clean water and safe sanitation. But although cholera was greatly feared in London and other cities during the nineteenth century, it was only one motive, albeit a prominent one, for sanitary reform. There were many more deaths routinely from other endemic infections. The need to remove human waste was a powerful factor too: the stink of

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faeces took cess pits out of houses, and the stink of the Thames led to the removal of faeces from the river (Chapter 1).

Since mid-2021, there has been a flare-up in the number of cholera outbreaks linked to the seventh global cholera pandemic, driven mainly by the *Vibrio cholerae* biotype El Tor, serogroup O1. In 2023, multiple countries were trying to contain cholera across the Horn of Africa (Somalia, Ethiopia, Kenya) and south-east Africa (including Malawi, Mozambique, Tanzania, and Zimbabwe). Cholera outbreaks have also been reported from Bangladesh, Haiti, Pakistan, and Syria. The primary causes are unsafe water, sanitation, and hygiene, and vaccine shortages, exacerbated by flooding (Malawi, Mozambique), conflict (Syria), and political instability (Haiti), probably magnified by climate change.

Cholera makes a small contribution to the number of deaths from diarrhoeal diseases worldwide, but attracts disproportionate attention, and remains a signal of the need for safe sanitation. That need is not easily satisfied during an outbreak, when long-term solutions are postponed in favour of short-term emergency responses—including the provision of clean water for drinking and washing, targeted vaccination to contain the outbreak, and reactive treatment to prevent severe illness and death. Between 2021 and 2023, emergency responses have been stretched: because under-resourced health services have had limited capacity for prevention and treatment, reported case fatality ratios have been exceptionally high (though with cautions about data quality): 1.9% on average globally and 2.9% in Africa, significantly higher than the targeted rate of less than 1%.[22]

The benefits of preventing a severe outbreak of disease linked to unsafe sanitation—whether it be cholera, dysentery, or typhoid—must be carried over to 'peace time' and added to sanitation's other advantages. One way to bridge the gap is by linking short- and long-term responses, for example by tying the provision of cholera vaccines, not just to immediate solutions (water treatment and storage, provision of soap, promotion of handwashing), but also to systematic analyses of the need for long-term investment in sanitation.[23]

Preferences and prohibitions

The poorest people in society are not just penniless, they are also relatively powerless. But they do sometimes have the power of refusal. Toilets,

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for example, can only contribute to safe sanitation if people are willing to use them.

For individuals, families, communities, and schools, toilets are not merely, or even mainly, for health. People are primarily concerned about whether toilets are available, accessible, and acceptable,[1,24] rather than with the management of excreta as a health hazard. Acceptability hinges on convenience, privacy, safety, and dignity, where personal preferences are rooted in cultural beliefs and social norms.[1,25,26]

Some of the reasons why people do not use toilets are obvious—because they are broken, blocked, dirty, or overflowing—and the technical solutions are obvious too. Less easy to understand and modify are long-standing sanitary behaviours based on local customs. Abundant research studies have shown how sanitary preferences are expressed in different settings: in Eastern Zambia, male heads of household prefer not to share toilets with women and children when there is a high risk of their being seen.[27] In Bangladesh, men avoid sharing toilets with women to prevent mutual embarrassment during menstruation, preferring instead to defecate outdoors.[28]

In India, Hindu beliefs about purity and pollution mean that open defecation is often personally preferable and socially acceptable. Open defecation is not a hardship to be overcome; it is believed to be good for health, pleasurable, wholesome, comfortable, and convenient.[29-31] Toilets, on the other hand, are thought to pollute the environment in and around dwellings.[27,30] Open defecation is gradually disappearing but the transition to toilet use is not irreversible.[32] In rural Laos, for example, some households unable to pay US$50 to empty a latrine have reverted to open defecation.[27]

In rural India, some government-provided, low-cost ('affordable') pit latrines are unused by Hindus because they have to be emptied manually—degrading work that is traditionally done by Dalits or 'untouchables' (Figure 7.1). Rural Hindus prefer more costly latrines, if they can afford them, which can be emptied by machine or which need not be emptied at all, or they defecate in the open.[29] Upmarket latrines with large pits or cemented underground tanks are seen as household assets whereas latrines with small soak pits, such as those provided by the government, are often unused.[29]

Indian Muslims, in contrast, are more likely to use the latrines that they own, whether private or provided by the government, and fewer defecate openly (Figure 7.1). In Muslim Bangladesh, a combination of approaches—subsidies, micro-credit, improved sanitation markets, and others—means

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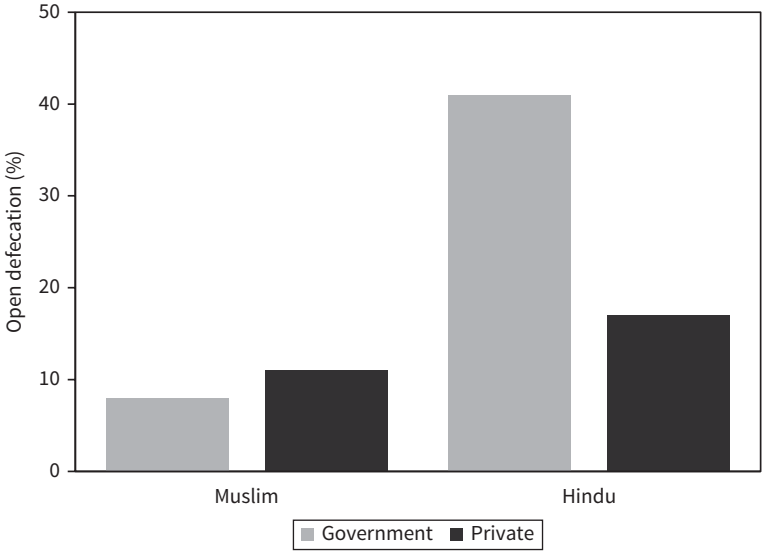

Figure 7.1 Open defecation in Muslim and Hindu communities of India. Percentage of people who live in households with latrines but practice open defecation, by religion and type of latrine (government-provided or private), in 5 states. Private latrines are typically large pits or cemented underground tanks, which are perceived to be non-polluting and more desirable. The government provides simple soak pits, which are smaller and less acceptable to Hindus.

Adapted from *Econ Polit Wkly*, 52(1), Coffey D, Gupta A, Hathi P, et al., Understanding open defecation in rural India. Untouchability, pollution, and latrine pits, pp. 59–66, Copyright (2017), with permission from the authors.

that the majority of households now use latrines, and open defecation has essentially been eliminated.[28,33]

In low-income neighbourhoods of Maputo, Mozambique, where toilets are mostly pit latrines, the experimental introduction of high-quality, pour-flush toilets improved the quality of people's lives.[34,35] The standard pit latrine (control group) is unlined with a squatting slab made of wood or tyres, no water seal (u-bend) providing a barrier to smells and flies, visible excreta, and little privacy. Pour-flush toilets (intervention group) had a water seal and concrete superstructure, discharging into a septic tank with soakaway. After four years or more of use, people were asked to give their perceptions of toilet facilities in terms of five criteria: disgust, privacy, safety, health, and shame. Those with pour-flush toilets reported a markedly

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higher quality-of-life score based on the five criteria, a mean difference of +0.34 above the control mean of 0.49 on a 0–1 scale (Figure 7.2). As attributes of sanitation, the intervention had its largest effects through safety and privacy, followed by health, disgust, and shame. Better health is a real and perceived attribute of improved sanitation, but this study reinforces the fact that toilets improve the quality of life in other important ways.

Poor sanitation presents special problems for women and girls. A lack of suitable facilities during menstruation means that girls miss days at school or college. Poor-quality toilets, and shared toilets, leave women vulnerable to violence.[28,36,37] In some settings without household toilets, women must defecate outdoors before dawn, or hold out until after dark.

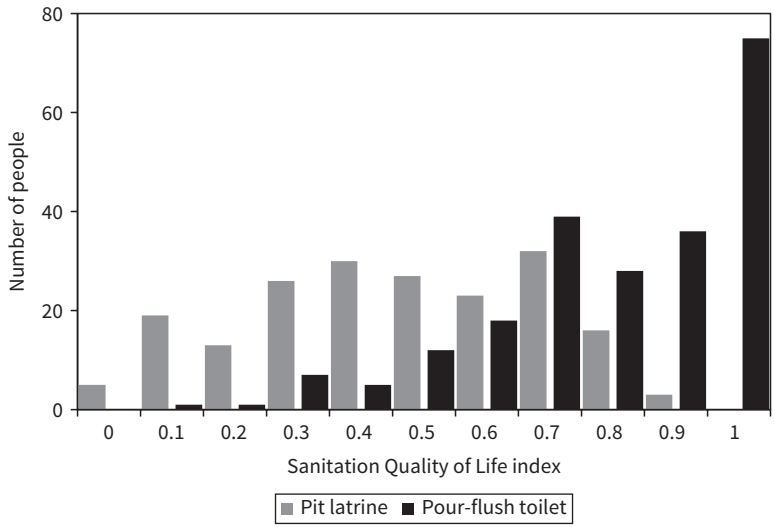

Figure 7.2 Sanitation and wellbeing. Distribution of scores on the sanitation-related quality of life (QoL) index among people using pit latrines (experimental control group) and higher-quality pour-flush toilets (intervention group) in urban Mozambique.

Source: data from *Health Econ*, 31(3), Ross I, Greco G, Opondo C, et al, Measuring and valuing broader impacts in public health: development of a sanitation-related quality of life instrument in Maputo, Mozambique, pp. 466–80, Copyright (2022), John Wiley and Sons; *BMJ Open*, 12(10), Ross I, Greco G, Adriano Z, et al, Impact of a sanitation intervention on quality of life and mental well-being in low-income urban neighbourhoods of Maputo, Mozambique: an observational study, pp. e062517, Copyright (2022), BMJ.

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These are some of the factors that determine the value of toilets and sanitation, and therefore the choices made by individuals and communities. They explain why simply providing a toilet, even if cheap and functional, does not guarantee that it will be used.[1] The difficulty of judging which of many factors are important in any particular setting may also explain why standard information, education and communication ('total sanitation') campaigns struggle to improve health by changing sanitary behaviour.[38,39]

Personal preferences are shaped by social norms and their observance is a form of cooperation. But sanitation demands other forms of cooperation too, including a consensus on the needs of a community of users with respect to offers from public and private providers. Some examples follow.

Ground-up meets top-down

Sanitary improvements made by individuals have limited benefits, both for those individuals and for whole communities. Leaky latrines contaminate the environmental commons, and pit latrines cannot easily be integrated into communal sewage systems. To maximize its social and cultural value, sanitation needs cooperation.

Community participation is one of the 'means of implementation' of SDG 6 but, as for other SDGs, little guidance is given on what the means should be. Clearly, there is a need for dialogue, which can take many forms, such as WASH committees at the village level (e.g. Laos, Rwanda, Tanzania, and Zimbabwe) or in workshops to develop national WASH policies and strategies (e.g. Costa Rica, Senegal).[40]

The purpose of the dialogue is to understand preferences and resolve differences. In six villages in rural Tanzania, the technologies that users found to be socially and economically acceptable (e.g. an improved floor toilet with a washable cement surface) were different from those recommended by sanitation experts (e.g. prefabricated concrete platforms, constructed by skilled artisans), and opinions differed among villages.[41] Among rural Quilombola communities in Brazil, dry systems were recommended by experts to reduce water consumption, but rejected by communities more comfortable with flushing toilets. Given local preferences for flushing toilets, for recycling water, and to create an environment attractive to tourists, the community opted for a system of evapotranspiration of blackwater (zero discharge from toilets), with greywater (from cooking and washing) used to irrigate banana tree gardens.[42]

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The demand for toilets and other sanitary products, and for removing human waste, is met by private as well as public suppliers worldwide.[1] Small-scale, private providers have been vital to the success of community-led total sanitation (CLTS) programmes, which originated in Bangladesh. The goal of CLTS is to eliminate open defecation, offering instead subsidized construction of toilets, household by household.[43] A key feature of CLTS has been the design and construction of latrines to a price rather than to a specification; capped prices make toilets affordable for poorer people. However, CLTS has been controversial as a 'radical approach to force people to deal with their shit'.[44] The force, sometimes mixing reward and shame, sometimes pitting social obligation against individual freedom, has been applied so that communities recognize the health risks of open defecation. The intention is to persuade households and communities to install health-safe facilities, pit latrines at least. The methods of CLTS implementation have been hotly debated, and the evidence for success through CLTS is weak and inconsistent.[45]

The Orangi Pilot Project (OPP), which began in 1980 in Karachi's largest slum,[46] has become a textbook story of communal action driven by the demand for sanitation.[47] But OPP also illustrates the difficulty of aligning interests, of creating a replicable model, and of expanding it nationally. Community social innovation, linked to appropriate technology (simple sewers), generated a low-cost sanitation system. Orangi residents were given technical and organizational support to build a sanitary latrine in each house, an underground sewer in each 'lane' (20–40 households), and a collector sewer in each neighbourhood, the latter feeding into a trunk sewer provided by the government. McGranahan and Mitlin explain the importance of cooperation that makes connections from households to cities:

> If the state did not provide the trunk sewer, the collector sewer would pollute the city, if the neighbourhood did not provide the collector sewer the lane sewer would pollute the neighbourhood, and if the lane did not provide their sewer the household's sewage would pollute the lane.

To borrow an Indian metaphor, it is not a question of dividing responsibility for 'big pipes' (government) and 'little pipes' (households);[46] rather, it is a question of sharing responsibility because neither big pipes nor little pipes are useful unless joined together.[48,49]

Connecting pipes is symbolic of what Elinor Ostrom and her collaborators called 'co-production', when ground-up meets top-down: providers

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and consumers, government planners and citizens, collaborate to make sanitation (in this case) work, and to reduce costs. Their example, in northeast Brazil, showed how condominial sewers, serving housing blocks inhabited by people on low incomes, were an affordable and effective sanitation system, provided local planners and contractors were willing to work with residents.[15,50] Condominial sewer pipes are smaller than conventional pipes and laid closer to the surface, and are less than half the price of a conventional sewage system. Co-production worked in northeast Brazil because residents co-designed the layout, making their own choices between cheaper and more costly options and, on the basis of agreement, committing to pay a fee. When co-workers on a specific project have other social connections—churches, housing, markets, schools—there are greater benefits to collaboration and greater costs in not doing so.[50] Such informal incentives for co-production are harder to create and maintain in large populations.

The mechanism of co-production depends on context. The Indian Alliance of NGOs was created in Mumbai in the 1980s, primarily to secure permanent housing for women pavement dwellers. Sanitation has been central to their strategy.[46] Women who came together to create credit and savings groups, a source of small loans, were also able to look after community toilets. Public toilets are built for anyone and owned by no one, whereas a community toilet is held jointly by a defined and responsible group of people. The improvements made to community toilets, incrementally and iteratively, contributed to the primary aim of upgrading houses and in giving residents security of tenure.

These examples of custom-made solutions (social, technical, financial) for sanitation on small scales (households, city neighbourhoods, villages) point to the challenges of replicating successful projects in other settings and on larger scales (cities and countries).

A nation of communities

Planning from the top down only succeeds when it accommodates needs expressed from the ground up—when supply satisfies demand. Nevertheless, national success in sanitation needs a national strategy, decisive leadership, and a means of implementation (as it did in nineteenth-century Europe; see Chapter 1).[51]

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Malaysia, Singapore, the Republic of Korea, and Thailand rapidly expanded the coverage of sanitation from the 1950s onwards. In each of these countries, strong leadership motivated by nation building came before increases in national wealth.[51] Leadership creates a common vision of the future that gives context to, instead of being driven by, budgets, risks, hazards, and discount rates. In the mould of nineteenth-century Europe, national strategies for hygiene, cleanliness, and public health, coordinated across different sectors of government, drove improvements in sanitation (Health in All Policies; Chapter 3).

The integration of sanitation in the economic development of these four countries is more easily described than replicated, as revealed by the mixed experiences of Pakistan, the Philippines, and Bangladesh.

Based on the success in Karachi (see earlier), the OPP approach to sanitation had been adopted by more than 90% of informal houses in Orangi by 2012—more than 100,000 households. But this is a long way from achieving safe sanitation nationwide.[47] In general, Pakistan has focused on eliminating open defecation rather than on the safe management of faecal waste. Consequently, there is extensive, continuing faecal contamination of surface and groundwater. Untreated wastewater from houses is routinely used for crop irrigation, magnifying the risk of human infection and the contamination of food produce. As a result, the incidence of diarrhoeal disease is still high even among the wealthiest households in Karachi.[52]

In the Philippines, the Pasig River Rehabilitation Commission (PRRC) was created to clean up Manila's grossly polluted river system, infamous for plastic waste. Between 1999 and 2017, the PRRC resettled 18,000 families living along the riverbanks of one tributary of the river, dismantled encroaching private structures, established environmental preservation areas along tens of kilometres of riverbanks, developed 17 of its 47 identified tributaries, diverted around 22,000 tonnes of solid waste, and made this typhoon-prone area more resilient to flooding.[53] Although a celebrated case study in urban renewal, the PRRC has also illustrated the problems of taking such an initiative beyond cooperative local communities to the city scale. Oversight at the level of municipal Manila has frequently failed, with regular complaints about the Pasig River 'cesspool'. However, public pressure and fears of flooding have prevailed: by July 2023, at the conclusion of a re-energized, two-year, clean-up drive, a further 1.5 million tonnes of waste had been removed, increasing the depth of the river, speeding up water flow, and further reducing the risk of inundation in nearby communities.

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In Bangladesh, the 2003–6 national sanitation campaign based on CLTS was successful in combining top-down government and ground-up community mobilization, and in shifting cultural norms so that open defecation became socially unacceptable in most parts of the country.[28] Even so, there is a big gap between eliminating open defecation and achieving safe sanitation nationwide. Rural and urban environments are still extensively polluted with human and animal faeces. Many Bangladeshis have switched, not to modern sanitation facilities, but to basic pit latrines shared with neighbours. Heavy use and uncertain ownership of these facilities compromises cleanliness, maintenance, and personal safety. And there remains a failure of cooperation in protecting people and the environment from harmful waste.[54]

Sanitation and sustainable development

Between 1990 and 2015, sanitation was linked to all eight Millennium Development Goals (MDGs). The MDGs were conceived as a partnership between richer and poorer countries to end extreme poverty (Chapter 1). Interventions targeted low-income countries with high burdens of disease, and MDG 4 aimed to reduce the mortality rate of children under five years by two-thirds.[1,55] In the event, the child mortality rate was halved in low- and middle-income countries between 1990 and 2015, from 91 to 41 deaths per 1,000 live births (or 12.7 m to 5.9 m deaths/year). Although short of the target, that result counts as one of the great achievements of the MDG era. Success was attributed more to medical care (drugs supported by vaccination) than to prevention upstream, by means including WASH. Reflecting the MDG emphasis on treatment rather than prevention, the incidence of infection with diarrhoeal disease pathogens was largely undiminished over 25 years (see also Figure 2.2).[43]

The unachieved MDGs (there were still 5.04 million mostly preventable deaths among children under five in 2019) have been carried over to, and absorbed within, the SDGs. Health goal SDG 3 includes target 3.2 on child mortality. The water and sanitation goal SDG 6, contributes to, benefits from, or otherwise interacts with at least 12 of the other 16 SDGs, including those concerned with poverty, nutrition, education, gender, and other inequalities, economic growth, life in water and on land, and sustainable cities.[56] Sanitation is therefore a test case for transdisciplinary action in the

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SDG era. Specifically, householders can invest in sanitation as a property asset, especially if they are homeowners rather than tenants.[46] The nutrients from excreta can be used as an agricultural fertilizer; solid waste can be converted to biofuel; wastewater can be recovered and purified or used for irrigation; sanitary engineering can help conserve water and prevent flooding; and sanitary structures (dykes, embankments, covered drains) can support access roads.[57] In the context of environmental protection, sanitation has a role in sustaining resource cycles—with potential benefits for whole ecosystems.[58,59] 'Regenerative sanitation' advocates resource recovery, reuse, and recycling, while 'ecological sanitation' aims to close nutrient and water cycles with minimal energy expenditure.[60,61] Among all these benefits are opportunities for business and tourism, which should be part of any comprehensive economic evaluation.

A snapshot of sanitation across the world today suggests that the transition from low to high coverage occurs mainly within the group of middle-income countries (Figure 7.3). Lower-middle and upper-middle-income countries increased the coverage of basic sanitation by 41% and 30% between 2000 and 2022, compared with 11% and 0.4% for low- and high-income countries. Exceptions prove the rule: few low- or lower-middle-income countries have population-wide sanitation coverage, but Malawi and Rwanda are above average, given their wealth. Conversely, few wealthier countries have low sanitation coverage; but Namibia and Gabon are lagging behind other upper-middle-income countries (Figure 7.3).

Malaysia, Singapore, the Republic of Korea, and Thailand (upper-middle and high-income) have shown how national sanitary systems are built alongside efficient institutions and good governance, with legislation and regulations, skills and technology, monitoring and evaluation for transparency and accountability, and collaboration across departments and disciplines (Chapter 3).[13,51,62] Most people living in high-income countries today have access to hygienic household toilets with safe waste disposal; the creation of a safe sanitary system is one of the mutually reinforcing processes of social and economic development. This is true in low- and lower-middle-income countries today as it was in Europe during the nineteenth century (c.f. Figure 1.1, Chapter 1). Historical (Chapter 1) and contemporary international comparisons (Figure 7.3) suggest that, with growing wealth, all countries will eventually gain the benefits of sanitation that are integral to personal, social, and economic wellbeing, but they can choose to do so more or less quickly.

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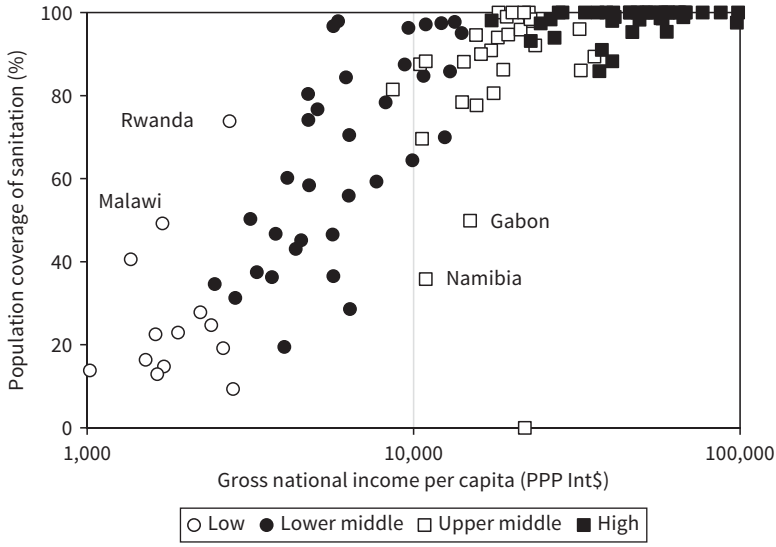

Figure 7.3 The sanitation transition. Association between sanitation and economic development: population coverage of 'basic sanitation' in countries grouped by Gross National Income (GNI, purchasing power parity, international $), 2022.

Source: data from World Bank, World Bank Open Data, Copyright (2023). Available at https://data.worldbank.org/ (accessed 18 September 2023).

Summary

Despite thousands of years of toilet culture and technology, and despite the obvious benefits of sanitation for health and wellbeing, 3.5 billion people alive today do not have access to a safe system for removing human waste. The installation of sanitary systems requires cooperation among many kinds of providers and users. Their collective goal is to combine the benefits for health with personal and social preferences for toilet use and hygiene, while exploiting other benefits from agriculture, energy, education, environmental protection, housing, and flood protection. For individuals, families, and communities, toilets are not merely, or even mainly, to protect health. Rather their acceptability hinges on convenience, privacy, personal safety, and dignity, where preferences are rooted in societal norms. Consensus in the 'co-production' of sanitary systems is easier to achieve

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through collective ownership in small communities; decisive leadership and large investments are needed to build sanitary systems at the national scale. Universal safe sanitation is costly—however, historical and contemporary international comparisons suggest that, with growing wealth, all countries will eventually have safe sanitation systems that are integral to personal, social, and economic wellbeing. Setting the many benefits against the costs will get them there more quickly.

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8
Climate change

A healthy price for carbon

> Hell is truth seen too late
>
> **Thomas Adam (*Private Thoughts on Religion*, 1814)**

Thomas Adam meant his dark warning to be taken literally, but it is an apt allegory for the threat of disastrous climate change. UN Secretary-General Antonio Guterres adopted the metaphor in September 2023, announcing that 'humanity has [already] opened the gates to hell'.

In the face of a different existential threat, the UK government booklet *Protect and Survive* (1976) explained 'how to make your home and your family as safe as possible under nuclear attack',[1] an exercise in adaptation (secondary prevention). E.P. Thompson's street-fighting parody, *Protest and Survive* (1980), might have been called 'prevent and survive' because it argued for unilateral nuclear disarmament (primary prevention).[2] Unilateral disarmament resembles climate change mitigation by a single country: cutting greenhouse gas emissions has limited effect unless matched by similar commitments around the world.

Seen through the doors of perception, an avoidable catastrophe might be allowed to happen if a major hazard is considered benign, of low or uncertain risk, and remote in space or time, and if the cost of preventing it seems to be high in relation to the expected benefit (Chapter 2). Those conditions, especially uncertainty about who will be affected when and by how much, and what they can do to prevent it, help to explain why action on climate change has been slow. They address the simple question posed by Naomi Oreskes: 'Why didn't they act?'[3]

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The magnitude of the climate threat is growing, in fact and in perception (even since the first edition of this book). Plenty of uncertainties remain but the risks and hazards linked to climate change, and their effects on health and wellbeing, are becoming clearer, greater, and nearer.

The case studies in preceding chapters have focused on aspects of health that are specific, temporary, or local. Climate change is a far bigger challenge to health and wellbeing because the effects of greenhouse gas (GHG) emissions are large, diverse, long-term, and global, but with plenty of unknowns. Operating on these large scales, the task is to turn cost, hazard, risk, uncertainty, and timing into a set of practical instruments of choice, which provide sufficient rewards to stimulate investment, and have sufficient impact to counteract climate change.

Health is never the sole driver or beneficiary of climate action, so the focus of this chapter is on health as one motivation for mitigating GHG emissions (primary prevention) and for adapting (secondary prevention) to the consequences.

The truth seen too late (epigraph) is another example of the preventionist's dilemma: the certain, immediate costs of divesting from the carbon economy weigh heavily against the uncertain, later (discounted) benefits of averting climate disaster.

Climate change

The facts about climate change are well-known and now widely accepted; scepticism about climate science has been marginalized.[4] In brief, the world is warming due to emissions of GHGs, predominantly carbon dioxide (CO_2), generated by combustion (fossil fuels, charcoal, wood), by anaerobic decomposition (wetlands, rice paddies), and from livestock (belching, manure).

The other principal GHGs are methane (from natural gas, livestock manure, mining, rice cultivation, solid waste, and wastewater treatment), nitrous oxide (from fertilizers, fossil fuels, nitric acid production), tropospheric ozone (from sunlight-driven chemical reactions), black carbon (soot) and chloro- and hydrofluorocarbons (used in air conditioners and refrigerators). In contrast to CO_2 and other long-lived GHGs such as nitrous oxide (half-life ≈ 120 years), methane, black carbon, tropospheric ozone, and fluorinated gases are 'short-lived climate pollutants' (SLCPs), persisting in the atmosphere for periods ranging from a few days to a few

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years. SLCPs occur at much lower concentrations than CO_2 and can be removed more quickly but have greater 'global warming potential' (GWP); the GWP of methane, for example, is 28–36 times greater than CO_2 per tonne of gas.

GHGs trap heat in the atmosphere, which in turn warms the land and oceans, thawing permafrost, acidifying and deoxygenating the seas, and melting polar ice and glaciers. Burning fossil fuels pushes up CO_2 concentrations in the atmosphere which will remain high for centuries, long after the fossil fuel era.

CO_2 emissions have increased more or less continuously since 1960. COVID-19 lockdowns reduced emissions by about 5% in 2020, but emissions rebounded in 2021 with economic stimuli and the roll-out of vaccines.[5] A record 40.8 Gt CO_2 e (equivalents) were emitted in 2021 (Figure 8.1). China and the US were together responsible for nearly half (45%) of the world's fuel combustion emissions, followed by the European Union, India, the Russian Federation, and Japan.

'Climate sensitivity'—the quantitative link between atmospheric CO_2 concentration and surface air temperature—is not precisely known. However, for every 10 ppm increase in CO_2 concentration, temperature increases by approximately 0.1°C. The global CO_2 concentration reached 420 parts per million (ppm) in 2023 compared with its pre-industrial level of 280 ppm, and is now higher than ever previously experienced by humanity. If CO_2 concentration continues to increase, doubling from 280 ppm to 560 ppm, we could expect global warming of roughly 2.8°C. More rigorous calculations, allowing for uncertainties, put the rise between 1.5°C and 4.5°C. If CO_2 emissions were halted now, atmospheric temperatures would not drop significantly for at least 1000 years.[6]

Energy consumption accounts for three-quarters (76%) of human GHG emissions, including transport, electricity and heat, buildings, manufacturing, and construction. The rest comes from livestock and crop cultivation (11.6%); industrial chemical processes and cement (6.1%); waste, landfills, and wastewater (3.3%); and land-use change including deforestation (3.3%).[7]

In 2022, fossil fuels still provided most of the world's energy: 30% came from oil, 25% from coal, 22% from natural gas, 20% from renewable sources (biofuels, solar, wind, hydroelectric, geothermal), and 4% from nuclear power. Between 2010 and 2022, growth in the consumption of renewable energy was 3% per year; growth in the use of fossil fuel energy was slower (0.9% per year) and slowing, but not falling.

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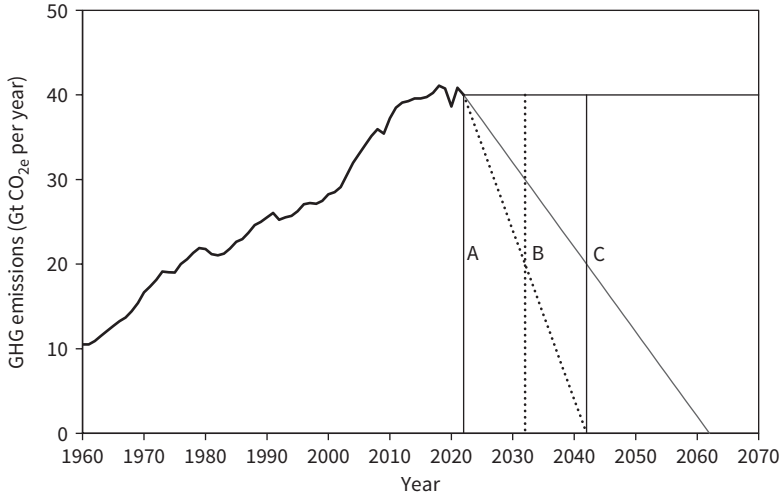

Figure 8.1 The threat of climate change represented by its cause: global emissions of GHGs. Data are for 1960–2022, with possible scenarios from 2022 onwards. Emissions are measured as billions of (giga-) tonnes of carbon dioxide equivalents (Gt CO_2e), and carbon budgets by the areas under the lines. The horizontal line from 2022 onwards represents approximate emissions due to policies that were in place by the end of 2020. Vertical lines mark the years from (A) 2022 at which carbon budgets for (B) 1.5℃ (dotted line) and (C) 2℃ would be exhausted with no additional policies (i.e. 2032 and 2042). Diagonals are examples of pathways to 'net zero' that give a 50% chance of not exceeding 1.5℃ (dotted line), and an 80% chance of not exceeding 2℃ (or a 17% chance of not exceeding 1.5℃; continuous line).

Source: data from International Energy Agency (IEA), Greenhouse gas emissions from Energy Data Explorer, Copyright (2023). Available at https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer (accessed 22 September 2023); Anderson K, Calverley D, How Alive Is 1.5? Part One—A Small Budget, Shrinking Fast, Copyright (2022), Climate Uncensored. Available at https://climateuncensored.com/how-alive-is-1-5part-one-a-small-budget-shrinking-fast (accessed 24 September 2023); Intergovernmental Panel on Climate Change, Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Copyright (2023).

Most fossil fuels are produced by a few, large petrochemical companies. In 2021, the eight largest, publicly listed, international oil and gas companies, and the seven largest state-owned national oil and gas companies together produced 42% of the world's fossil fuels by volume.[8]

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While some renewable energy technologies are now familiar (solar and wind power, electric vehicles), other low-carbon innovations (heat pumps, household energy-saving devices) are still relatively expensive or unknown to the public at large. Cheaper and more efficient renewable energy technologies (e.g. for carbon capture and storage) are highly desirable, and they are emerging, but the most urgent task is to implement the carbon cutting solutions that already exist. The principal obstacles to producing clean energy are less technological and more economic, political, institutional, and cultural.[9-11] The economic factors, for example, are only partly about the (falling) unit costs of hydrogen, nuclear, solar, and wind technologies. They are also about the costs of installation, maintenance, and operations; of acquiring land to position infrastructure; of electricity distribution across national grids; of boosting storage capacity; of borrowing for investment; of building resilience to energy market volatility; and of creating disincentives for fossil fuel exploitation. In short, all of the factors that affect the large-scale diffusion of innovations.[12]

Alongside the ingenuity that has created renewable energy technologies, there is beauty in the powerful regulatory tools that stimulate their application—the Paris Agreement (2015), carbon taxes, emissions trading systems, the benchmark price of carbon (2017), the Social Cost of Carbon, and the tools of legal inference and accountability. Technologies and regulatory instruments used in combination will provide the best remedies for climate change, as described in the following sections.

Targets to mitigate climate change

The targets for mitigation of GHG emissions are clear: the 2015 Paris Agreement, reinforced by the 2021 Glasgow Climate Pact, states that global warming should be kept to 'well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change'.[13-15]

Climate science presents three big challenges for investment in mitigation. The first is global ownership. CO_2 emissions produced anywhere in the world add to the atmospheric concentration of these gases everywhere, because the lifespan of circulating CO_2 is measured in centuries. Each nation knows that local reductions in CO_2 emissions have little effect globally, unless matched by international commitments. We need to be 'all in

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it together', and yet free-riding on the efforts of others is commonplace.[16] Besides, the perceived costs and benefits of mitigation vary among key actors—the public, their governments, and agricultural, construction, and energy industries.

The second is uncertainty—the enemy of decisive investment. The horizontal line in Figure 8.1 shows that GHG emissions produced annually with policies implemented by 2020 are expected to stay around 40 Gt CO_2e. By 2070, however, emissions could be anywhere between 20 and 60 Gt CO_2e, without any further policy changes. Following this path to 2100 would lead to a warming of between 2.2°C and 3.5°C.[13] Inevitably, there is even greater uncertainty in the downstream consequences of CO_2 emissions and warming—for the economy, society, and environment, including health and wellbeing.[17]

The Paris Agreement was remarkably successful in taking steps to manage ownership and uncertainty, producing a global scientific and political consensus that warming should not exceed 2°C, and preferably 1.5°C (though, in 2024, 1.5°C is a fading hope). Agreement on these goals has diminished, if not entirely dispelled, doubt as a deterrent to investment in low-carbon technologies, directing attention instead to the strategies needed to meet the goals.

Challenge number three is 'the fierce urgency of now'.[18] Drastic and rapid reductions in GHG emissions—by shutting down coal, oil, and gas production—are needed to keep warming below 2°C, and very drastic reductions to keep warming below 1.5°C. These criteria are based on the carbon budget, which is the cumulative net CO_2e that can be emitted before breeching a global warming threshold. The cumulative emissions from 1850 to 2019 are estimated to be 2,390 Gt CO_2e in total. To have a 50% chance of limiting global warming to 2°C, emissions must be kept within a remaining carbon budget that was 1,350 Gt CO_2e at the start of 2020; to keep to 1.5°C, the remaining budget was only 500 Gt CO_2e.[19] At the start of 2023, a separate analysis put these two figures at 1,200 Gt CO_2e and 250 Gt CO_2e, respectively.[20]

After the carbon budget has been exhausted, emissions must remain at 'net zero' in order to stay below the agreed temperature limits; that is, the GHGs produced must be no greater than the quantity removed from the atmosphere.[21,22] Under policies already implemented in 2020, the carbon budget for 1.5°C would be depleted in roughly a decade and the budget for 2°C in two decades. If emissions were reduced linearly from 2022 onwards, net zero would have to be reached by 2042 for 1.5°C and by 2062 for 2°C

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(Figure 8.1). In view of all the evidence, the chance of limiting warming to 1.5°C looks vanishingly small.

The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer is cited as a successful precedent to the 2015 Paris Agreement. Both the Montreal Protocol and Paris Agreement aim to reduce emissions of harmful gases, but there are differences that made the Montreal Protocol easier to enact. Montreal focused on the primary cause, setting achievable targets and dates for phasing out specific ozone-depleting substances (ODS), especially the chlorofluorocarbons that damage the ozone shield against ultraviolet light. In contrast, Paris is directed at an outcome, limited warming, and requires countries to make only voluntary commitments to reduce GHG emissions as 'nationally determined contributions'. Montreal required the substitution of ODS with a few available and affordable alternatives to serve specific functions—refrigerants, fire suppressants, insulators, and aerosol propellants. Paris requires decarbonization of the entire global energy system.

The Paris Agreement is a formidable challenge; evaluating the links between climate and health can help meet that challenge.

Health effects of climate change

The diverse hazards of climate change have direct and indirect effects on health.[8,13,23-25] The direct effects include illness, injury and death from air pollution, droughts, floods, heatwaves, low and high temperatures, storms and wildfires, plus effects mediated through natural systems, such as diseases transmitted by climate-sensitive arthropod vectors. The indirect effects operate via most of the pathways that link health to the Sustainable Development Goals (SDGs)—through poverty, environmental degradation, food insecurity, inadequate sanitation, disrupted health services, homelessness, forced migration, social and economic inequality, among others.

The deleterious effects on health are wide-ranging: a 2021 synthesis of 94 systematic reviews reported effects on infectious, respiratory, cardiovascular, and neurological diseases, plus overall mortality, most commonly linked to meteorological (temperature, humidity, precipitation) and extreme weather events (droughts, flooding).[25] The measurement of interactions across different domains represented by the SDGs is a work in

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progress,[26,27] but one synthesis of communicable diseases concluded that hundreds of human infections can be aggravated by climate hazards.[28]

According to WHO, there could be 250,000 additional deaths each year due to climate change between 2030 and 2050, from causes including heat stress, diarrhoeal and vector-borne diseases, and undernutrition.[23] But this is no more than a starting point for analysis: considering all the direct and indirect effects together, the total impact on health is certain to be far greater.[24] Taking a high-level view, Pearce and Parncutt calculated that there is one premature death for every 1,000 tonnes of fossil fuel burned (creating 3,700 tCO_2).[29] The implication is stark: if warming reaches or exceeds 2°C above pre-industrial levels this century, it will cost the lives of a billion people before 2100.

A virtue of the approximate '1000-tonne rule' is that it offers a method of assigning responsibility for social, economic, and health impact in proportion to GHGs emitted. This is one way to approach the main challenge facing health specialists—which is to turn the measured harms of climate change on health, and the benefits of relieving those harms, into practical instruments of mitigation and adaptation.

Mitigation: primary prevention

Mitigation (primary prevention) slows climate change at source – by reducing GHG emissions. Adaptation (secondary prevention) reduces the effects of GHGs, at any point after emission.

Mitigation has multiple co-benefits, where reducing GHG emissions and their physical consequences (droughts, floods, fires and storms) goes hand in hand with health and other gains made from improved nutrition (low-meat, plant-rich diets), transportation (lower vehicle emissions, active travel), energy supply (air quality) and waste management (improved water treatment).[30,31] These pathways not only protect health from climate change, but also promote better health more widely, in the short and long run.

The benefits of cleaner air are especially large. Ambient (outdoor) air pollution, including long- and short-lived GHGs mixed with toxic gases (SO_2, NO_x, ground-level ozone) and fine particulate matter, caused an estimated 4.1 million deaths in 2019, more than double the total in 1990 (2.0 million).[24,32,33] Household air pollution from solid fuels is also a cause of many deaths, though fewer in 2019 (2.3 million) than in 1990 (4.4 million).

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Air pollution affects nearly every organ in the body, contributing to a wide variety of illnesses—acute lower respiratory infections, chronic obstructive pulmonary disease (COPD), ischaemic (coronary) heart disease, lung cancer and stroke (Chapter 6). And cutting air pollution improves health quickly, a return on investment with little discount (Chapter 2).[34] In Ireland, a ban on indoor smoking reduced minor ailments within a few weeks: breathing difficulties, cough, phlegm, irritated eyes, painful throat, nasal itch, runny nose, sneeze, and wheeze. Just as quickly, there were measurable reductions in COPD, ischaemic heart disease, stroke, and all-cause mortality. Likewise, a variety of health and social benefits were reported within weeks of closing a steel mill in Utah: fewer people with respiratory illnesses, fewer premature births, and fewer school absentees. In China, within two months of air pollution controls prior to the 2008 Beijing Olympics, lung function improved among healthy and asthmatic adults, there were fewer doctors' visits by asthma patients, and fewer deaths from cardiovascular diseases. In Nigeria, clean cooking stoves have benefitted women and children, even within the term of a pregnancy, leading to higher birthweights, fewer premature births, and reduced perinatal mortality.[35]

Health and the price of carbon

The singular advantage of mitigation is that climate change has one main cause—GHGs produced by burning fossil fuels. That single cause points to a principal target for action—the price of carbon. The purpose of putting a price on carbon, monetary or non-monetary, is to discourage the production of CO_2 and other GHGs, driving emissions to net zero (or lower) fast enough to keep global warming below 2°C (and ideally 1.5°C).

The main question here is: how can health contribute to, and benefit from, the price of carbon? The rest of this section is a brief account of the multiple, underexploited ways by which health can influence decisions about mitigation.

The principal financial instruments are monetary carbon prices (implemented through carbon taxes, emissions trading systems, carbon offsets and environmental regulations), renewable energy subsidies (while ending subsidies for coal, oil, and gas production), infrastructure investments (agriculture, public transport), grants and loans for clean technologies, and incentives to produce and use energy efficiently (tax credits and

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rebates for energy-efficient appliances, home insulation, car-pooling, and public transport).

A **carbon tax** imposes a fixed levy based on the quantity of GHGs emitted. Its purpose is to set a price for producers and consumers that reflects all the costs of GHGs to the economy, environment, and society, including health.[36] There is usually a gap, for example, between the full cost of vehicle fuel to society and the price paid by the consumer at the pump. That gap is, in effect, a subsidy to the motorist (although the subsidy might later be devalued by poor health linked to air pollution).[37] Raising the price of carbon lowers fuel consumption, cuts the emission of GHGs, and reduces illness due to air pollution.[38]

One reason why governments should be enthusiastic about carbon taxes is that revenues can be reinvested in managing climate change on behalf of taxpayers. On the other hand, both producers and consumers might resist immediate price increases that are intended to pay for longer-term environmental and health benefits. For consumers especially, carbon taxes tend to be regressive in penalizing those who can least afford, for example, higher fuel prices (this assumes that fuel is a necessity; c.f. tobacco and sugar taxes; Chapter 6). And consumers with tight budgets have an extra reason to reject higher fuel prices: they get little personal reward for their contribution to mitigation.

In 2018, French government proposals to raise fuel (especially diesel) prices were dropped after weeks of public protest. The context and timing of these proposals were critical: street protests steered by the 'gilets jaunes' (yellow vests) movement were only partly about carbon taxes; they were also motivated by government policies on wealth taxes and the minimum wage, by rising costs and falling living standards, in which health would have played a minor role (c.f. France's more successful approach to tobacco taxation; Chapter 6). This experience offers a general lesson: investigate rather than assume the criteria for consumer choice.

In 2023–24, carbon taxes and prices are too low to effectively cut GHG emissions.[39]

Emissions trading systems (ETS) put a cap on carbon emissions. Participants who produce GHGs can buy or sell emissions permits, which creates a market for carbon allowances (cap-and-trade). Systems that trade in carbon build on previously successful ETS created for sulphur dioxide (SO_2) and nitrogen oxides (NO_x) in the 1980s and 1990s.[40] GHG producers can stay within the cap by managing their emissions; alternatively, they can

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buy permits that allow them to produce more GHGs. Exceeding the permitted limits may incur financial penalties.[41]

Among emissions trading schemes, the European Union currently oversees the world's largest carbon market.[42] In 2023, the EU-ETS limited emissions from around 10,000 installations in the aviation, energy, and manufacturing industries, covering 40% of the EU's greenhouse gas emissions. According to the EU, installations covered by the ETS reduced emissions by 35% between 2005 and 2021.

Carbon offsetting operates by pricing the removal of GHGs, for example by carbon sequestration (e.g. planting trees that absorb CO_2) or by producing energy from renewable sources (solar, wind). The price is embodied in a transferrable carbon credit (or offset credit), usually measured in US$ per tonne of CO_2e. Carbon credits can be purchased to offset emissions made elsewhere. As of 2023, offsets have doubtful and unstable value in a largely unregulated global market. Among many unresolved problems are contestable methods for measuring carbon sequestration and verification; and for ensuring that offsets are additional and durable, not duplicative and temporary. Even with measurement uncertainties, it is clear that emissions reductions from some projects have been vastly overstated.[43,44] Although these problems can be resolved, the priority for mitigation is to reduce GHG emissions and therefore minimize the need for offsetting.[45]

What carbon price would keep global warming under 2°C? The World Bank's High Level Commission on Carbon Pricing (HLCCP 2017) decided that the benchmark price should have been US$40–80/t$CO_2$ in 2020 rising to US$50–100/t$CO_2$ by 2030.[46] Health was included in HLCCP calculations as the value of reducing mortality due to one main factor—air pollution—which was priced at US$50–380/t$CO_2$. In a similar exercise, the IPCC calculated a desirable price of US$115/t$CO_2$ in 2023.

These targets are benchmarks set by a mix of evidence and expert opinion. They are indicative because, for example, fuel choices depend on the comparative, fluctuating costs of carbon and non-carbon energy sources. Guide rails are set by plausible lower and upper bounds: if a carbon tax is set too low, it is cheaper for emitters to pay the tax and continue polluting rather than, say, investing in low-carbon technologies. If the cap is set too high in a cap-and-trade system, carbon is made too abundant to yield a price that discourages emissions.

Managing common, transnational resources, such as low atmospheric GHG concentrations, stable temperatures, glaciers, and polar ice sheets, needs cooperation across nations.[47] To signal cooperation, the price of

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carbon needs to be high everywhere—reflecting worldwide ownership of the climate crisis. But the remaining carbon budget is owned by no-one in the global commons.[47] If prices vary widely across countries we can expect 'carbon leakage', where those who produce the highest carbon emissions relocate to places with more relaxed policies.

In 2023, 73 carbon pricing initiatives—largely a mix of taxes and ETS—were already implemented, scheduled, or under consideration around the world. Globally, however, the price of carbon is presently too low to prevent and repair the anticipated social, economic, environmental, and health costs of climate change. The EU-ETS is exceptional, generating prices that exceeded EUR 100/tCO_2 (≈ US$ 110/tCO_2) for the first time during 2023, close to the HLCCP and IPCC targets. Worldwide, however, less than 5% of GHG emissions were covered by a direct carbon price at or above the range recommended by the HLCCP in 2030, with much variation between countries.[48] To compound difficulties, fossil fuel subsidies undercut carbon prices: 69 of 86 countries surveyed in 2019 had a net-negative carbon price as a result of subsidies.[8]

To support mitigation, fossil fuel subsidies should be replaced by **renewable energy subsidies**. As an alternative to carbon taxation, a primary goal of the US Inflation Reduction Act (IRA 2022) is to stimulate an economic shift away from fossil fuels by investing hundreds of billions of dollars in renewable energy, in lowering GHG emissions, in electrification and energy efficiency, and to promote domestic supply chains. The beauty of this approach to mitigation is that boosting local investment in, for example, renewable energy technologies bypasses the intractable problem of global ownership. The IRA is expected to accelerate decarbonization, reducing 2005 GHG emissions by 43–48% within 30 years (by 2035). But the US will not achieve net zero emissions with the IRA alone.[49]

The 'social cost of carbon' (SCC, normally expressed as US$/$tCO_2$) is the monetary value of GHG harms to society, including harms to health. Besides helping to quantify taxes and subsidies, the SCC can be used to **regulate GHG emissions** directly.[50,51] In New York and Illinois, for example, SCC influences the value of 'zero-emission credits' paid to electric utilities under clean energy legislation. The proposed US federal SCC was US$ 190/tCO_2 in 2022, close to an independent evaluation of $185/$tCO_2$.[52] When SCC is mandatory in a strict regulatory environment, as in the US, it is an effective instrument for pricing health and other social benefits into climate policy.

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In summary, incentives based on the price of carbon are stimulating divestment from fossil fuels and the scale-up of renewable energy technologies. Putting health into the tools that create these incentives is an underdeveloped science. But carbon taxes and other ways of setting carbon prices will not be sufficient to mitigate climate change quickly, even including the value of health. So other measures are needed too.

Climate, health, and the law

Judicial procedures are notoriously slow but the role of litigation is growing in climate change mitigation (and adaptation). Regulations that embrace the health and social costs of carbon (above) are just one example of the law in action. Medical and legal systems use different criteria to judge the strength of evidence linking cause and effect. So, the standard criteria for establishing a causal link, for example between environment and disease, need to be interpreted alongside, for instance, the 'balance of probability' and 'beyond reasonable doubt' as used, respectively, in criminal and civil law.[53]

By mid-2023, the Grantham Research Institute had logged more than 2,300 pieces of climate legislation worldwide, two-thirds filed since 2015.[54] More than half of climate cases had direct judicial outcomes that were favourable to climate action. Domestic legal protections—such as the right to a healthy environment—linked to domestic climate legislation, played a major role in cases brought against governments. In one exemplary case, applicants successfully challenged the South African government over its failure to protect people from air pollution caused by coal-fired power generation. The number of cases filed against corporate actors is also growing, notably by US cities taking on major oil and gas companies.

But litigation works in the other direction too: 'climate-washing' lawsuits are challenging the accuracy of green claims and commitments, and questioning whether good environmental, social and governance practices (ESG) comply with US federal and state laws.

Strengthening arguments for accountability, 'attribution science' has extended methods of inferring causality: providing evidence that attributes specific effects, for example on health or environment, to their determinants.[55] Attributing droughts, floods, heatwaves, hurricanes, and wildfires to GHG emissions, and evaluating the health impacts of such events, is now routine.[56] The first 'extreme event attribution' study focused on the 27,000

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excess deaths linked to Europe's 2003 heatwave. An attribution analysis found it 'very likely' (>90%) that anthropogenic climate change at least doubled the risk of the heatwave, causing approximately 500 excess deaths in London and Paris.[57,58]

It is not possible to prove that human-induced environmental change damaged the health of a particular individual, but a court of law might accept that it has, considering the weight of epidemiological and medical evidence.[53] The death of nine-year-old Ella Kissi-Debrah has become a cause célèbre, not least because the victim was a vulnerable child. Living close to the South Circular Road in Lewisham, London, she was regularly exposed to high levels of air pollution. She suffered a fatal asthma attack in February 2013 after three years of seizures and many hospital visits for breathing problems. In 2019, a London court ordered a full inquest into her death under the Human Rights Act. In 2020, Ella became the first person in the UK for whom air pollution was certified as a contributing factor in her death, catalysing advocacy for stronger regulations and other policies to reduce air pollution (c.f. glyphosate weed killer as a cause of cancer; Chapter 2).[59] Taken together, arguments about causation from epidemiology, medicine, and the law constitute a powerful instrument of accountability for events linked to climate change.

Given the huge challenge of making large and rapid reductions in GHG emissions, and the slow progress achieved by the early 2020s (Figure 8.1), mitigation will need strong backup from adaptation.[60]

Adaptation: secondary prevention

Adaptation (downstream, secondary prevention) is inferior to mitigation (upstream, primary prevention) in the sense that its effects are remedial and relatively small in scale. On the other hand, adaptation responds to specific and predictable local threats, with interventions that often require lower capital expenditure and are likely to provide rapid returns on investment: flood and fire prevention, resilient agriculture, clean water and safe sanitation, and population resettlement. An extra advantage is that it is not necessary to ascertain that climate change is the underlying cause of foreseeable events before deciding to take action. Furthermore, many forms of adaptation, particularly in cities, are under the control of local authorities who provide, independently of national governments, a large proportion of energy, transport, water, sanitation, and health services.[30]

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Climate change adaptation is a growth industry, but still greatly underfinanced in a world that is largely underprepared.[61,62] A total of US$ 665 billion was spent on climate change in 2020, but only US$ 56 billion (8.4%) of that was allocated to adaptation, mostly from public rather than private funds.[63] Within the scope of adaptation, health is still a low priority. In 2021, for example, the Green Climate Fund approved $726 million for 15 adaptation projects and $414 million for eight mitigation and adaptation projects. But only 15% ($166 million) of funds went to projects with benefits for health and wellbeing.[8]

This lack of resources helps to explain why programmes of adaptation and resilience have so far been fragmented, local and incremental, and reported few health benefits.[64] But there are successes to build on. One systematic review of evidence identified 99 studies from 66 from low- and middle-income countries.[65] Reports of adaptation covered flooding, rainfall, drought, and extreme heat, predominantly through behaviour change, and through improvements to infrastructure and technology. Positive outcomes included fewer cases of infectious diseases, improved water and sanitation, higher agricultural yields, and greater food security. Unsurprisingly, low-income populations have the largest adaptation gaps. And adaptation is harder when managing multiple interacting risks, for example between food, energy, water, and health.[13]

One striking success of adaptation is the long-term decline in deaths linked to disasters (Figure 8.2). The number of recorded disasters has increased in each decade over the past century, partly due to climate change, but also through more complete reporting. The number of injuries has increased too, and so have the economic costs. But the number of deaths linked to these disasters has continued to fall, due partly to improved early warning systems and more effective emergency responses.[66]

Because climate change largely magnifies existing threats to health, direct action to contain those threats has advantages beyond the benefits of adaptation. Whereas the health co-benefits of mitigation are obtained by actions that coincidentally reduce GHGs (e.g. while eliminating air pollutants), the health co-benefits of adaptation amplify the rewards for containing a single problem that is only partly attributable to climate change.

Deaths due to excess heat are a case in point. An estimated 37% of warm-season deaths can be attributed to anthropogenic climate change globally, with increased mortality on every continent.[67] The goal, of course, is to prevent all heat-related deaths, including the 63% that are not related to climate change. The methods include: encouraging heat-resistant behaviours

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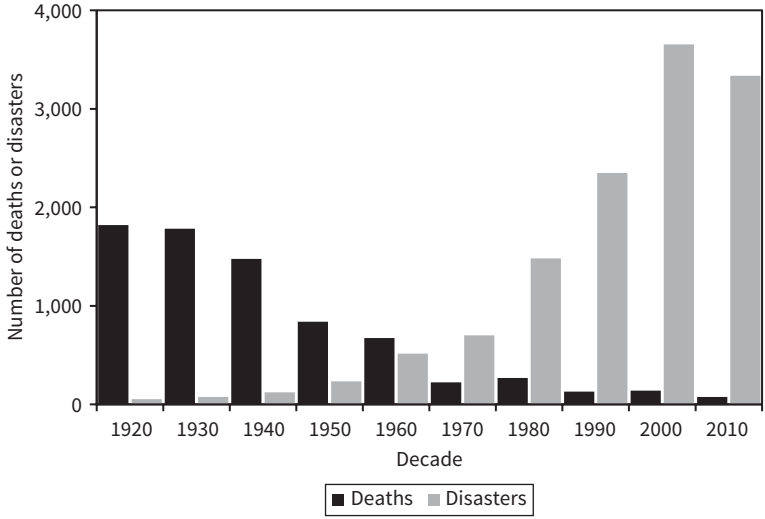

Figure 8.2 Adaptation to disasters. Rising numbers of disasters (grey) but falling numbers of deaths (black) reported worldwide over the century, 1920–2019. Disasters are classified as droughts, floods, extreme weather, extreme temperatures, landslides, and wildfires. Some, but not all, are due to climate change. Decades are marked by the first year, e.g. 1920 for 1920–9.

Source: data from EM-DAT, The International Disaster Database, Copyright (2023) (accessed 28 September 2023); Ritchie H, Rosado P, Natural Disasters, Copyright (2022). Available at https://ourworldindata.org/natural-disasters (accessed 28 September 2023).

(hydration, modified dress, restricted sun exposure, heat stress guidelines), heat-proofing homes, schools, and workplaces, and creating green urban spaces.

Flooding, too, has causes beyond climate change. In 2022, an estimated 3.6 million people were exposed to flood risks in the US.[68] High-resolution mapping and forecasting suggest that, without adaptation, twice as many people will be at risk by 2050 (7.2 million). Population growth will account for 75% of the increase in risk, and climate change only 19%, with 6% due to the joint effects of climate and population. Mitigation will do little to reduce flooding before 2050. But predictable flood risks can be managed to protect everyone who might be exposed, by restricting development in high-risk areas, and by introducing flood protection mechanisms, including stringent building codes and measures to prepare for emergencies. These conclusions apply widely: over the past four decades at least, human

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settlements around the world—from villages to megacities—have spread rapidly into hazardous flood zones.[69]

As with mitigation (c.f. French fuel taxes), successful adaptation depends on resolving competing interests. In 2018, monsoon flooding killed at least 400 people in Kerala state, India, and left a million people homeless.[70] In Kerala, as elsewhere, adaptation depends on understanding why illegal stone quarrying, deforestation, and construction, all of which aggravated the flooding, were permitted to breach environmental laws.[71]

Wildfires, like floods, are exacerbated by climate change and can be managed by tackling the underlying causes. Among the causes are drying by deforestation, slash-and-burn agriculture, the loss of wetlands and peatlands, and housebuilding in fire-prone areas.[72,73]

Adaptation is a safety net for mitigation failures. But it is more than that: the rising incidence of droughts, floods, storms, and wildfires should be a stimulus to resolve long-standing threats to lives and livelihoods that have been made worse by climate change.

Tipping points: triggers for action

Gradual change breeds hesitation in the response to an evolving emergency.[74,75] As psychologist Daniel Gilbert put it: 'Many environmentalists say climate change is happening too fast. No, it's happening too slowly.'[76] There are plenty of supporting data: a 2018 study by the European Environment Agency examined 88 slow-moving environmental problems; in 84 of these cases, policy inaction allowed problems to worsen despite years of warnings.[75]

Shock is one remedy for prevarication. Possible 'tipping points' in the geophysical climate system mean that there is potential for large, abrupt, non-linear, and irreversible changes, which have happened repeatedly in the past.[77] Lenton and colleagues have identified several tipping points that are possible with 1.5–2°C warming, though none have yet happened. They include the collapse of the Greenland and West Antarctic ice sheets, die-off of low-latitude coral but reefs, and the widespread and abrupt thawing of permafrost.[78-80] Worse still, exceeding a threshold in one system (ice sheets) could heighten the risk of crossing boundaries others (deserts, ocean currents, forests), with cascading effects between physical and ecological systems.

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There is much uncertainty about whether and when critical thresholds will be crossed, and with what consequences on what time scales. Lenton and colleagues have exposed some of the key factors in a variation of the theory laid out in Chapter 2. They quantify threat (T) as the risk that an event (tipping point) will happen (r), multiplied by the size of the hazard (damage caused, H) and by urgency, which is the reaction time to a future event (τ) divided by the time left to prevent it (P). Thus, $T = Hr\tau / P$. The threat becomes an emergency when hazard, risk, and urgency are high. In particular, when the reaction time is longer than the remaining intervention time, $\tau / P > 1$, the system is said to be no longer under control. The opportunity to prevent, for example, a more rapid decline of Arctic and Antarctic ice sheets vanishes.[81]

Just as geophysical systems have tipping points, so do response systems. 'Sensitive intervention points', where 'a small kick … may have an outsized effect', have the potential to cause large and rapid changes in the social, financial and political systems that govern action on climate change (a 'nudge' over a precipice; Chapter 2).[82-84] The contemporary analysis of disproportionate (non-linear) effects builds on studies of the diffusion of innovations, and of the precipitating social effects of fires, stinks, smogs, and mass shootings (Chapters 1 and 2).

Examples of accelerating responses to climate change abound, albeit with intermittent retreats. Commerce is increasingly sensitive to the threat posed by climate change and other man-made environmental disasters. In parts of the energy industry, a growing fear of 'stranded assets' (fossil fuels priced or regulated out of use) is forcing a switch from strategies that wantonly impede decarbonization to strategies that capitalize on the inevitable and imminent change. For some, decarbonization is becoming the shrewd business choice, with mutually reinforcing effects—selling dirty assets, buying cleaner energy, investing in low-carbon products, and decarbonizing supply chains.[85] Others, however, are extracting as much revenue as possible from fossil fuels until they become useless.

Principles for Responsible Investment (PRI), an investors group with trillions of dollars under management, predicts 'abrupt and disruptive' climate policies during the 2020s.[86] Their 'inevitable policy response' forecasts that EU and US ETS will generate carbon prices of US$65–75/tCO$_2$ by 2030.

Beyond carbon trading, there is mounting concern among economists that asset prices are adjusting too slowly to climate change, in view of the slow progress on both mitigation and adaptation. They fear that, when the risks and consequences of crop failures, high food prices, coastal flooding,

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and mass migration are properly understood, there will be a sharp and contagious correction to market prices, leading to an economic mega-shock. Only after another global financial crisis—and after many people have been hurt—will public policy and private behaviour step up to the climate challenge. Too little too late is the hallmark of failures in prevention (c.f. Cleave on sugar; Chapter 6).[62]

Some large pension funds are also taking a stand against 'short-termism'. Japan's Government Pension Investment Fund believes that a focus on short-sighted returns leaves their portfolios open to catastrophic, systemic risks. Their stated intent is to price in the environment and the long-term wellbeing of workers and communities.[87] That intent is shared by other major pension funds—in Canada, Netherlands, New York, and Norway, albeit with constraints.[88]

The insurance industry also thinks that the world is unprepared for climate change, and expects the insurance business to grow. Only a quarter of losses due to droughts, earthquakes, floods, and storms were insured at the start of the 1980s. Today the average figure is still no more than half, and well under 10% in low-income countries.[89] Insurance is a mechanism for managing unpredictable risks (Chapter 4), and will help to drive climate resilience, for example by offering lower premiums to policyholders who adopt early warning systems, building standards that allow for extreme weather events, drought-resistant crops, and measures to protect watersheds.

Rapid, government-backed transitions in the adoption of clean energy sources and technologies benefit health more and less directly.[90] During the 1990s, Sweden made a comprehensive shift to energy-efficient lighting in commercial buildings within a decade. To drive the change, the government directly purchased 30,000 lighting units in a pilot phase and supported their installation. They introduced technical standards and quality assurance, plus subsidies and methods for bulk purchase and procurement. Market penetration jumped from 10% in 1996 to almost 70% by 2000.

Between 1983 and 1998, China's National Improved Stove Program promoted the invention and distribution of energy-efficient cooking stoves, increasing coverage from 1% of the Chinese market to more than 80%, reaching half a billion people after 15 years.

Brazil made two separate but rapid transitions from petrol to ethanol fuels for private cars. Beginning in 1975, the Proálcool programme scaled up production so that 90% of all new vehicles could run on ethanol by 1981. Then in 2003, lower fuel taxes encouraged motorists to buy flex-fuel

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vehicles (FFVs), which could run on any blend of fuel, from zero to pure ethanol. FFV drivers could switch between various blends of gasoline and ethanol depending on price and convenience. FFV sales grew from 17% of new cars in 2004 to 90% in 2009.

Now the imperative is to switch to electric vehicles (EVs). Road transport contributes more than 15% of energy-related GHG emissions globally. Norway has taken the lead on EVs, though reluctantly at first, following public protest. Members of the pop band A-ha bought an electric Fiat Panda in 1989 and, refusing to pay road tolls, they successfully campaigned for registration tax to be waived for all electric cars. As more models became available, sales accelerated. But further intervention by a belatedly enthusiastic government was critical too: developing a nationwide charging network, giving EVs access to bus lanes so as to cut school and work commuting times, among others.[83] By 2023, more than 80% of new cars bought in Norway were all-electric. Norway has the funds to back EVs and other clean energy sources—the world's largest Sovereign Wealth Fund was created in 1990 to invest surplus revenues of the petroleum industry on environmentally and socially responsible (ESG) activities. Norway has, however, been selective on ESG, continuing in 2023 to invest in oil and gas exploration.

Due to a combination of government incentives, manufacturing innovation, and consumer enthusiasm, EV sales are accelerating globally. The share of EVs among all new cars sold worldwide increased at an average of 50.2% per year between 2010 and 2022, which means annual EV sales increased more than threefold between 2020 and 2022.[91]

Rapid changes in the primary source of energy are possible too, at least at the national level. The decommissioning of coal-fired power plants in Ontario, Canada, beginning in 2003 was strongly motivated by public health. Coal produces SO_2, NO_x, and small particulates, which are associated with asthma, bronchitis and other lung diseases, and an exceptionally high death rate per unit of energy produced.[92,93] Eliminating coal would, it was estimated, cut pollution-related illnesses from 330,000 to fewer than 2,500 per year and nearly eliminate associated deaths, with an added economic dividend. To make the transition, the government of Ontario invested in hydroelectric, solar, wind and nuclear power, in addition to improving the efficiency of energy distribution.[90]

The UK has decarbonized its power sector faster than any other large country, essentially by making carbon relatively costly, in a variety of ways.[94] UK coal production has been in decline for a century, but a series of

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critical incidents accelerated that decline. Motivated by air pollution rather than by GHG emissions, the Clean Air Act (1956) was precipitated by the 'Great Smog' of December 1952 (Figure 8.3; Chapter 2). Less coal burnt has meant less pollution: over decades, SO_2 emissions have been driven downwards by the elimination of coal, aided by reducing the sulphur content of liquid fuels and by fitting flue gas desulphurization units to the remaining coal-fired plants (Figure 8.3).

Two more triggers accelerated coal's demise in the UK, and hastened the removal of toxic gases and airborne particulates. In 1991, the EU lifted restrictions on using natural gas as a source of power. That encouraged the

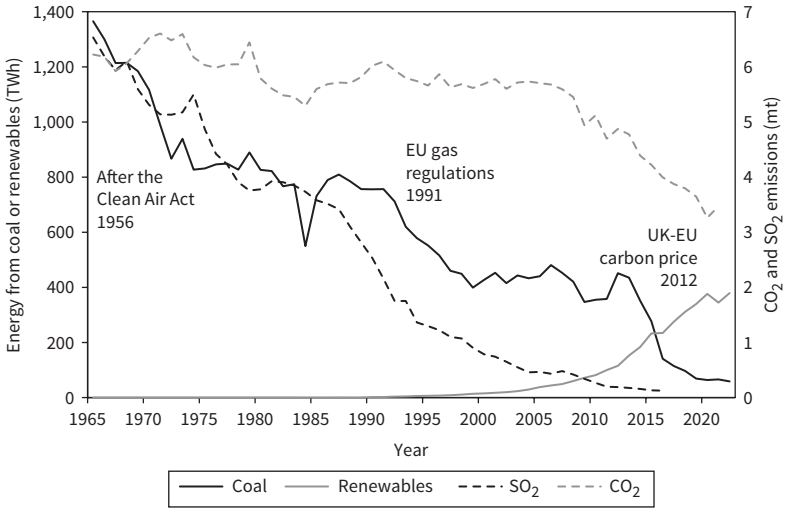

Figure 8.3 Tipping points and climate-health co-benefits. Coal and renewable sources of energy (including biofuel, hydroelectric, solar, wind) in the UK, and atmospheric pollutants SO_2 and CO_2, 1965–2022. Three accelerators of coal decline were the Clean Air Act (1956), EU gas regulations (1991) and UK-EU carbon pricing (2012). Reductions in toxic SO_2 emissions tracked the decline in coal, but CO_2 emissions fell slowly until the switch from gas (which replaced coal) to renewable energy sources began in the early 2000s.

Source: data from Department for Environment Food & Rural Affairs, Emissions of air pollutants in the UK—Sulphur dioxide (SO2), Copyright (2023). Available at https://www.gov.uk/government/statistics/emissions-of-air-pollutants/emissions-of-air-pollutants-in-the-uk-sulphur-dioxide-so2 (accessed 29 September 2023); Energy Institute, Statistical Review of World Energy, Copyright (2023). Available at https://www.energyinst.org/statistical-review/ (accessed 3 October 2023).

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construction of gas-fired power stations, which had lower capital costs than coal (Figure 8.3). In 2012, the total cost of carbon was pushed up further, when the price generated by the EU-ETS was added to a fixed UK tax. Consequently, gas became cheaper than coal, which limited the number of hours coal plants could generate electricity. With the introduction of tighter regulations on air quality and the falling cost of renewable energy, coal plants became even less profitable, and most were irreversibly closed.

In contrast to SO_2 produced by coal, CO_2 emissions from fossil fuels remained high until the early 2000s, when renewable energy (predominantly wind) began to replace gas (Figure 8.3). The reduction of short-lived SO_2 greatly improved UK air quality, with benefits for health. In contrast, the reduction of long-lived CO_2 in the UK alone has little effect on climate change because CO_2 concentration anywhere depends on CO_2 emissions everywhere.

Sun and wind now generate electricity more cheaply than fossil fuels. But growth in their share of energy production is dampened by continuing fossil fuel exploitation, inertia in electricity market design, inadequate grid infrastructure and energy storage capacity, high financing costs, and political choices.[94]

The UK was one of the first countries to set a target for achieving net zero (by 2050). And by early 2023, nearly half (48%) of UK electricity came from renewable sources. Based on current technologies and costs, all of the UK's energy demand could be met by wind and solar – by a wide margin.[95] But in September 2023, on the cusp of an election year, short-sighted politics intervened: in contrast to the vastly ambitious US Inflation Reduction Act (see earlier), the UK government postponed the phase-out of new petrol and diesel cars and of gas boilers, and downgraded requirements for household energy efficiency. It put the expansion of offshore wind energy on hold, resisted measures to cut air pollution (urban low emissions zones), cancelled investment in railway infrastructure, and issued new licences for the exploitation of North Sea oil and gas fields. A new UK government took office on 5 July 2024, promising a return to investment in clean, homegrown energy production, focusing on wind, solar, tidal, nuclear, and other novel energy sources.

Globally, the demand for coal reached an all-time high in 2023, accounting for about 36% of the world's electricity generation. The main reason is that Asia's rapidly growing energy needs, especially in China, India, and Indonesia, cannot yet be satisfied by renewable sources, so coal and gas fill the gap.[5] Consequently, the share of energy from all renewable

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sources is still growing slowly, at an average of only 1.8% per year 2005–23 (c.f. 50.2% annual growth of EVs among car sales, see earlier).

This mix of forward and backward steps lays down a challenge: intensify the search for additional switches that could mitigate climate change by accelerating the transition to a low-carbon future; at the same time, invest heavily in adaptation.

Summary

Climate change is prevention's greatest challenge—its effects on health and wellbeing will be large, diverse, long-term, and global. This chapter examines how health can benefit from, contribute to, and motivate actions to mitigate and adapt to climate change. The main challenge for mitigation (primary prevention) is to raise the price of carbon, quantitatively and qualitatively, so as to drive global greenhouse gas emissions to 'net zero' or lower, and fast enough to keep global warming below 2°C. The task for health experts is to price health into the cost of carbon so as to influence decisions made via carbon taxes, emission trading schemes, renewable energy subsidies, and the application of laws and regulations. Because mitigation is slow, adaptation (secondary prevention) will play an accelerating role in protecting lives and livelihoods. Local adaptation to counter foreseeable local threats—droughts, extreme temperatures, flooding, vector-borne diseases—gives relatively predictable returns on investment (c.f. global mitigation) but is greatly underfunded. As stimuli for action, specific initiatives to improve health and wellbeing yield co-benefits that exceed those obtained by mitigation and adaptation alone. The pressure for systemic and transformative action mounts with every extreme weather event—that pressure has triggered sudden and rapid switches towards cleaner and healthier energy technologies. Many more of these switches are needed to avert climate disaster.

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9
Future positive
The conditions for health

> The doctor of the future will give no medicine, but will interest his patient in the care of the human frame, in diet and in the cause and prevention of disease
>
> **Thomas Edison (1903)**

Twenty-two centuries after Pien Ch'iao (epigraph, Chapter 1), Thomas Edison restated history's enduring ambition. But he must have realized, like many who came before and after, that we pay a price to care for the human frame, both to improve health as well as prevent disease—counted in money, time, effort, information, trust, and willpower. And if we pay that price, we want to be sure of the reward—the return on investment.

Consequently, the decision to protect and improve health is conditional: it is better than falling ill, but not at any price. Another century on from Edison, we are still asking how to resolve the ubiquitous dilemma: faced with a future threat to health, is it better to risk illness and bet on a cure? Or invest upfront in staying healthy? If conditions do not favour investment in health over disease, how can those favourable conditions be created?

Seeking incentives (evidence and reason) instead of issuing directives ('take nothing on authority'), the history (Chapter 1), principles (Chapter 2), and case studies (Chapters 3–8) examine how people make choices about health. They investigate *what* should be done in different circumstances; more importantly, they examine *why* anyone would choose to do it. As a discipline, public health says much about the *what* (science), with too little understanding of the *why* (economics). A proliferation of

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general global solutions deters studies of local incentives and motivations. Consequently, much scientific advice about what to do lies fallow.

The ideas about how choices are made focus here on health, but they invoke fundamental questions about how people exploit opportunities and avoid threats when faced with a risky, uncertain future. The principles have been developed and applied by specialists of all kinds, from actuaries (e.g. life insurance, pensions) to zoologists (e.g. animal behaviour, evolution by natural selection). But the core ideas are common to all disciplines, so they can be exchanged between them, for example across all the domains of sustainable development (framed by the SDGs). Trans-disciplinary exchange is vital because the best choices might come from ecology, economics, education, epidemiology, ethology, or from some other unpredictable source.

Chapter 2 gives an overview of the main ideas, and also lays out some basic facts about health choices. One myth laid to rest is that very few resources are invested in prevention, rather than medical treatment. It is true that small fractions of health budgets are spent on prevention (typically 2–4%), as made plain by the international System of Health Accounts (SHA). But it is not true for society as a whole, where a great variety of social, economic, and environmental improvements have contributed directly and indirectly to health and longevity. This helps to explain why about half of the reduction in mortality rates globally over the past three decades was due to prevention (lower incidence rate) rather than to the treatment of illness (lower death rate).

And yet the vast, persistent, and avoidable burden of disease presents many unanswered questions: Why is low-cost preventive care neglected by medical services? Why is pandemic panic usually followed by tranquil neglect? Why is tackling the world's number one infectious killer, tuberculosis, a perennially low priority? Why do so many people still smoke cigarettes, one of the most dangerous consumer products ever invented? Why do billions of people still not have access to safe sanitation, despite thousands of years of toilet technology? Why has action to combat climate change been slow, even as droughts and floods become commonplace? These are some of the questions that stimulated the six case studies in Chapters 3–8, with answers summarized below.

Common principles, diverse applications

Assembling the common principles leads to a testable idea: investment in protecting health as an asset is more likely when a high-risk, high-value

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hazard can be averted rapidly, with certainty, and at relatively low cost. Similar criteria apply when the goal is to enhance health and wellbeing, not merely to prevent disease (Chapter 2). The total benefit is the sum of health gained plus illness averted (health not lost). This is 'prevention' in the largest sense, a companion to health promotion.

Investments are usually transactions between health providers (supply) and consumers (demand). The transactions are of many kinds, and they operate through collaboration, cooperation, competition, and conflict. There have been too few studies of the nature of these interactions, and how they affect health choices. Presumptive analyses that guess the criteria for choice a priori—a feature of much routine economic evaluation—are in danger of producing the right answer to the wrong question.

The case studies show how health choices are influenced by the circumstances in which they are made. Adding to the principles above, Box 9.1 contains a checklist of factors that commonly affect these choices. No single factor is dominant in any setting—each located in a different part of the health system—but every setting has a leading theme: cost, risk, hazard, time, wellbeing, and scale. Figure 9.1 illustrates these themes comparatively—highlighting multiple determinants of choice in plots of threat and opportunity (asset, hazard, risk) through time (years elapsed, cohort age, or inferred from comparative economic wealth), extracted from Chapters 3–8 and guided by the concepts in Chapter 2.

There is another reason why choice depends on circumstance. Each element of gain and loss—whether it be cost, hazard, risk, uncertainty or time—depends on facts (information based on data) and on perceptions of the facts (opinion based on values). Perceptions and values are personal and circumstantial, so global generalities—such as standard, cost-effective solutions—invariably need local interpretation. This approach gives preference to 'positive' over 'normative' economics, favouring the investigation of 'what is' before prescribing 'what should be'. This is an advertisement for natural history—for making unconstrained observations before defining and testing specific hypotheses.

The rest of this chapter is a resumé of the case studies, aided by the summary graphics in Figure 9.1.

Cost (affordability) is an everyday constraint on healthcare, but cost restricts prevention in more ways than imagined by standard economic evaluations. First, prevention is an add-on to a core service, which is dominated by medical treatment. Prevention looks relatively affordable when

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Box 9.1 Ten factors that guide health choices, which emerge from the case studies

- **Costs and benefits determine motives**, but are useful only when the value of each is agreed by those who are making a choice.
- **Choices are made comparatively** among the feasible options for intervention; a benefit/cost ratio is of little value in isolation; primary prevention is ideal, but secondary prevention is often a better interim investment; for some infectious diseases (e.g. tuberculosis) early medical treatment is currently the best form of prevention.
- **Choices are bounded by constraints and contingencies**—modes of pathogen transmission, the immunology of vaccine development, entrenched behaviours, and social norms.
- **Choices are made in view of trade-offs** up and down the causal chain of illness; e.g. primary prevention tends to be sensitive but not specific, and secondary prevention the reverse.
- **Investments should be linked to rewards**, monetary or non-monetary, or they are unlikely to be viable; the ability to match costs and benefits is usually easier on smaller (community healthcare) than larger scales (national sanitation systems, global mitigation of greenhouse gases).
- **Interventions should serve everyone who needs them** but the criteria for success change in scaling up from innovation (e.g. inventions competing in markets) to population-wide impact (e.g. government intervention to achieve Universal Health Coverage).
- **Benefits can change disproportionately with costs**, being subject to feedback loops, tipping points, and other non-linearities, e.g. investment in prevention relieves pressure on medical services, which may release funds that can be reinvested in prevention, further reducing the burden of medical care, and so on.
- **Choices depend on the types of transactions between consumers and providers**; there are frequent mismatches to resolve between individual consumers (assessing personal risk), government health authorities (managing the burden of disease in whole populations), and commercial manufacturers (selling unhealthy products).

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- **Technologies (drugs, diagnostics, vaccines, devices) and other instruments (finance, taxes, laws, regulations) can shift the balance from treatment to prevention**, but innovation of all kinds suffers from under-investment in research to protect health, as distinct from research to control disease.
- **Health accounts underpin accountability**, as well as providing data for monitoring and evaluation; methods for tying effects to causes are central to epidemiology (what did it) and to the law (who did it). Based on shared data and metrics, 'attribution science' exploits the power of both together.

the costs of treating illness are disproportionately large, as they are in wealthier countries (to the right of Figures 3.1(a) and 9.1(a)).

Second, funding for preventive care is not transferrable from urgent medical care, so prevention needs additional, protected investment, which at first supplements but eventually supplants (partly, at least) the treatment of illness.

Third, affordability affects patient demand as well as health service supply, and there is generally lower demand for prevention than for treatment. The majority of the 14 sentinel indicators that track progress towards Universal Health Coverage are for preventive care, including family planning, immunization, sanitation, and managing risk factors for chronic disease. But unless patient demand matches service supply, UHC will be unachievable.

All of that said, with extra, protected funding, and a match between supply and demand, preventive care can make rapid health gains by mitigating major risks, especially high blood pressure and blood sugar, alcohol and tobacco use, physical inactivity, poor diet, overweight and obesity, air pollution, and vaccine-preventable and vector-borne infections. Under these conditions, controls on major risks are among the most powerful interventions in public health.

Uncertainty deters investment in the prevention of epidemics. Why invest in preventing something that might have little impact, happen somewhere else, and in the distant future? Tactics to manage unpredictable disasters are routinely used by the insurance industry. They include pooling

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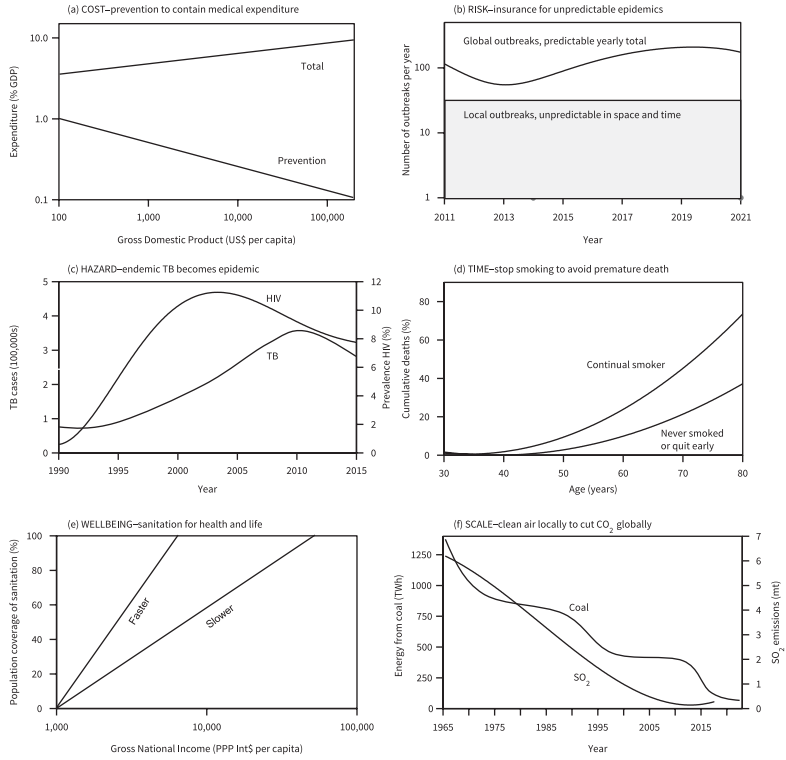

Figure 9.1 Threats and opportunities that influence health choices in six different settings, extracted and simplified from the case studies in Chapters 3–8. (a) cost: more preventive care helps to contain growing medical costs in health services as nations become wealthier over time, (b) risk: pooled epidemic data suggest global insurance mechanisms (e.g. finance, surveillance) to combat locally unpredictable outbreaks, (c) hazard: neglected endemic diseases stimulate greater action when they become epidemic emergencies, such as TB driven by the spread of HIV in South Africa, (d) time: quit tobacco smoking when young to prevent premature death, (e) wellbeing: better health contributes to the quality of life provided by safe sanitation, (f) scale: abandoning coal as an energy source in the UK cut toxic SO_2 emissions (immediate local benefit), a step towards mitigating CO_2 emissions through the introduction of renewable energy technologies (gradual global benefit). Each chart is explained in more detail in the text and in Chapters 3–8, with data sources.

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risks and sharing the costs which, for infectious diseases, can be achieved in a variety of ways: early detection and response systems for multiple pathogens, including Disease X (Figures 4.2 and 9.1(b)); mechanisms for sharing genomic and other surveillance data; platform technologies (templates) for the development of new diagnostics, drugs, and vaccines; and collaborations through the international conventions and regulations. Primary prevention is ideal but secondary prevention is often more efficient: the (primary) spillover of infections from animals to humans is unpredictable; stopping its (secondary) spread by surveillance, diagnosis, isolation, quarantine, and vaccination is vital and feasible.

Although a predictable risk can favour investment, it also tends to devalue a **hazard.** The prevention of stable endemic diseases such as tuberculosis is neglected, even though these diseases kill millions of people each year. The neglect of TB as a hazard is compounded by geographical distribution: TB has largely been contained in the rich world; most cases and deaths nowadays occur in the poorest countries.

But there are remedies for the neglect, which could be applied anywhere. The first is to enhance the role of TB control in strengthening primary health care, deviating from the long history of separatism in TB control. The personal risk of developing respiratory TB is low (about 0.1% per year on average) so the demand for preventive drug treatment is also low. But those who develop this debilitating and potentially lethal disease (untreated case fatality ≈ 50%) certainly do want medical care. A patient suffering with prolonged cough does not usually know the cause; TB requires a differential diagnosis, which is a point of entry for the treatment of any respiratory disease with similar symptoms. The early diagnosis of TB, followed by chemotherapy, is currently the best form of treatment *and* prevention, stopping transmission as well as saving lives. Integrated care aligns the needs for TB with the needs for all respiratory diseases, plus other conditions including diabetes and HIV/AIDS.

The second remedy for neglect is to redefine TB as a health hazard. Normal, endemic diseases stimulate abnormally strong public and political reactions when they become epidemic. Beginning in the 1990s, South Africa suffered a triple TB-HIV hazard: the spread of HIV infection dramatically magnified the number of TB cases, an unfolding epidemic that was further aggravated by the emergence of strains extensively resistant to TB drugs (XDR-TB; Figures 5.3 and 9.1(c)).

The variable experience of southern African countries in scaling up antiretroviral therapy for HIV/AIDS and TB control (Botswana quicker, South

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Africa slower) holds another lesson: whatever the virtues of new technologies for TB control—including better diagnostics, drugs, and vaccines—none will succeed without understanding the local means and motives for implementation.

Time-delayed illness and death are the enemies of chronic disease prevention. Approximately two-thirds of lifelong smokers will eventually die of a tobacco-related illness, but that has little effect on the decision to smoke another cigarette today, a pleasure nurtured by tobacco companies. Time discounting makes the present more valuable than the future. The decision to quit requires immediate pain (fighting addiction) set against longer-term gain (feeling healthier, and cutting the lifetime risk of heart attack, stroke, cancers, and respiratory diseases; Figures 6.2 and 9.1(d)). Consumers are ultimately responsible for 'behavioural' risks to their health, but the behaviours in question are also those of manufacturers and governments. The burden of choice on consumers is lighter when shared, and governments in particular have the means to intervene between commercial supply and consumer demand, if they choose to do so. The most effective instruments of government are the most forceful—taxes and regulations—especially for the control of single, major causes of illness such as tobacco and sugar. In practice, governments under pressure from manufacturers tend to under-tax and under-regulate harmful commodities, so other enticements are needed too.

Among the other enticements are ways of combining health gains (through physical activity, social engagement) with losses avoided (preventing overweight, diabetes, and mental illness). The greater need, however, is to empower public demand for government actions that favour health, and disempower commercial interests that promote the harmful consumption of alcohol, salt, sugar, tobacco, ultra-processed food, and other causes of chronic disease. As Hilary Cottam put it: 'solutions require our participation … whether we think about diabetes or climate change, good ageing or good education, we have to be active agents of change.' Elinor Ostrom agreed: 'no government can be efficient and equitable without considerable input from citizens.' Public agency is key.

Wellbeing and the quality of life are primary goals of safe sanitation. Even though sanitation has been identified as the greatest medical advance since 1840 (when the British Medical Journal was founded), toilets are not merely, or even mainly, to protect health. Rather their acceptability hinges on convenience, privacy, personal safety, and dignity, where preferences are rooted in societal norms. Health makes an additional contribution. All

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these factors together determine whether and how, for example, high-grade pour-flush toilets are preferred to low-grade pit latrines. The installation of safe sanitary systems depends on cooperation among many kinds of providers and users. At a local level, sanitation can succeed by community 'co-production'; at the national scale, it needs visionary leadership, and large, long-term budgets (Figures 7.3 and 9.1(e)). To make the case for financing, sanitary systems should count health alongside multiple parallel benefits from agriculture, energy, education, environmental protection, housing, and flood protection.

Geographical and population **scales** are critical in understanding and combating climate change. The main challenge for mitigation (primary prevention) is to raise the price of carbon, quantitatively and qualitatively, so as to drive global greenhouse gas (GHG) emissions to 'net zero' or lower, and fast enough to keep global warming below 2°C and preferably below 1.5°C (ideally we would eventually return to 0°C, the pre-industrial level). The main task for health experts, working alongside others, is to price health into the cost of carbon, so that the value of health influences decisions made via taxes, emission trading schemes, renewable energy subsidies, and the application of laws and regulations. Embedding health in carbon prices is a developing science, with unexploited possibilities.

Mitigation has been slow, in part because the world's remaining carbon budget is owned by no one and consumed by everyone in the global commons. One partial solution is to reduce the global problem to a local one, using health gains as a lever to make climate gains. Substituting renewable sources of energy for coal removes toxic atmospheric pollutants such as sulphur dioxide (SO_2) as well as the principal GHG, carbon dioxide (CO_2).

In practice, the elimination of coal as a source of energy in the UK has taken a century, intermittently accelerated by qualitative (laws e.g. the Clean Air Act 1956) and quantitative forces (rising carbon prices). People living in the UK gained large health benefits from cleaner air as SO_2 emissions declined (Figures 8.3 and 9.1(f)). But people living around the world have gained smaller benefits from lower CO_2 emissions in the UK, for two reasons. One is that CO_2 production fell slowly when coal was replaced by gas; the decline quickened only with the switch to renewable energy, provided mainly by wind farms. The other is that CO_2 persists in the atmosphere for many decades, so CO_2 concentration anywhere in the world depends on CO_2 emissions everywhere. Therefore local initiatives to mitigate GHG emissions, as in the UK, must be replicated worldwide.

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GHG emissions are still rising globally, so mitigation needs a backup plan. Adaptation (secondary prevention) will play a rapidly increasing role in protecting lives and livelihoods. Local adaptation to counter foreseeable local threats holds appeal, not only because it is imperative, but also because there are relatively predictable rewards (c.f. mitigating GHGs) from safeguarding against droughts, extreme temperatures, flooding, and vector-borne diseases.

Climate change mostly amplifies existing environmental threats, rather than creating new ones. The need for adaptation strengthens the existing arguments for tackling these threats. Consequently, protection against floods and wildfires, or against an increased risk of malaria, can benefit many more people than are put at risk by climate change alone.

In summary, understanding the reason why people prefer to take a chance on sickness and cure is the key to persuading them when and why they should invest in health instead. This book has identified some of the means of persuasion: investigate rather than presuppose which criteria are used to make health choices, and how they depend on the way health is valued; embed those criteria in tools that people use to make decisions; build systems for accounting (inclusive costs and benefits of prevention) and for accountability (attribution, liability and responsibility); offer ways to improve health, not merely ways to avoid losing it; measure and manage the perceptions linked to health hazards; and exploit the logic of choice to insure against the risk of unlikely disasters, to increase the present value of future threats, to foster cooperation as a basis for health investment, to map out the pathways from innovation to large-scale impact, and to remedy the under-investment in health research (as distinct from disease research).

Summary

This book explores ways to resolve one of humanity's most enduring dilemmas: whether to invest in staying healthy ('prevention' in the larger sense, both protecting and improving health) or take a chance on illness and medical treatment ('cure')? Resolution of this age-old dilemma begins with a timeless truth: the benefits of good health come at a cost; prevention is not better than cure at any price. Any study of health choices should begin without preconception—observing 'what is' (positive economics) before prescribing 'what should be' (normative economics), because rational choices are the logical consequences of subjective values. The six case

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studies in Chapters 3–8 investigate how choices depend on the circumstances in which they are made: in health services (cost of prevention in PHC), and for epidemics (managing risk and uncertainty), endemic infections (recalibrating perceptions of hazard), chronic diseases (valuing the future, today), sanitation (health and the quality of life), and climate change (mitigation and adaptation on large and small population scales). Facing a variety of threats and opportunities, each of these challenges demands a different set of solutions to achieve the same ultimate goal—health as WHO's 'state of complete physical, mental and social wellbeing'.

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